COMMUNAL AERIALS and COAXIAL RELAY PRACTICE

by GORDON J. KING, Assoc. Brit. I.R.E., Grad. T.P.A.

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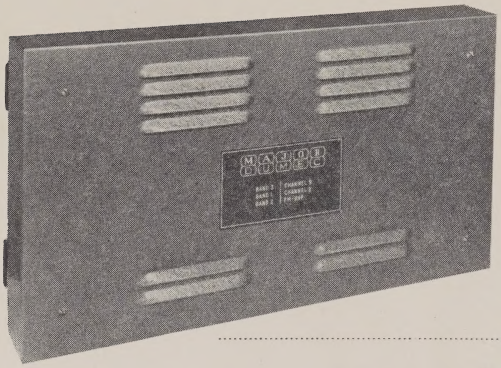

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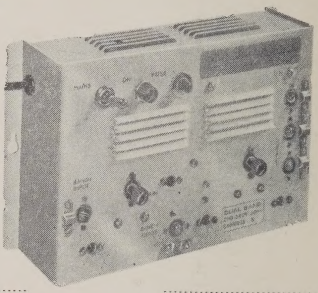

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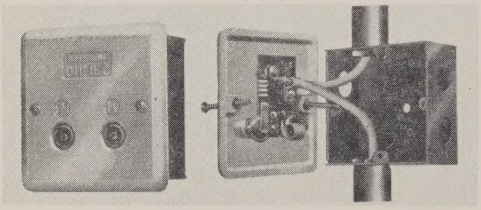

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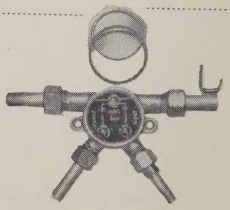

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COMMUNAL AERIALS AND COAXIAL RELAY PRACTICE

By Gordon J. King, Assoc. Brit. I.R.E.

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FOREWORD

This book was produced from a series of articles written for "Electrical and Radio Trading," to whom I record my thanks for permission to use them in this form. My thanks also go to Roy C. Norris, the Technical Editor of that magazine, for his valued assistance in preparing and editing the articles for original publication.

I also record my thanks to Mr. C. V. Lovely of "The Irish Radio and Electrical Journal," for permission to use an article written for that magazine, an adaptation of which comprises Chapter 1.

I think I am right in saying that this is the first book to be published in Great Britain dealing exclusively with the practice of coaxial relay systems and communal aerials. I should like to emphasise the term "coaxial relay," for I feel there has been unnecessary ambiguity in the use of such terms as "r.f. relay," "h.f. relay," "l.f. relay" and so on.

I think it wrong, just because a relay system uses coaxial cable instead of multi-cables or balanced pairs, to put it into the category of r.f. or h.f. Indeed, coaxial relay systems are able equally to distribute low-frequency and high-frequency signals, and in the future I am sure that coaxial systems will be called upon progressively to distribute relatively low-frequency modulated carriers in addition *to "carrier-frequency" signals.*

Within a single coaxial cable can be locked a complete radio and television spectrum. It is thus the cable system *and* not *the frequency of the signals carried that is the dominant factor. If the cable system is likened to a road and the signals to the traffic coaxial cable is adequately able to handle all traffic within the boundaries of importance to the relay operator and film industry.*

The term l.f. relay was coined in the early days of audio distribution. It would appear that in the future sound distribution (and possibly television sound accompaniment) will not be at physical audio, but on relatively low-frequency carriers, via the medium of co-axial cable. This technique is being developed in Great Britain and already has limited use on multi-cable relay systems.

In conclusion, I should like to thank the coaxial relay industry for its help in making this book possible, and the manufacturers for freely supplying details of their equipment. Almost a decade has passed since I engineered my first coaxial relay system, using Band 1 and later Band 3 with channelised amplifiers. Since those days much has happened in the relay world, and coaxial relay is now developing into an industry of its own. Now to the future of "coaxial relay" . . . .

G.J.K. *Brixham, Devon, 1962.*

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CHAPTER ONE

A History of Television Relay

IT was little more than eight years ago when coaxial relay was seriously investigated as a means of distributing interference-free radio and television programmes to individual households over large areas by cable. Unlike the original method of relaying sound and television at audio-frequency and low carrier frequencies via the medium of multi-core cable, coaxial relay requires only a single unobtrusive coaxial cable. Through this can be propagated many signals each carrying sound and/or vision modulation. Moreover, in essence the original method requires the use of low-frequency carrier signals which, in turn, demand the use of special receivers. This is not so with coaxial relay since the carrier signals can be arranged to correspond to the frequencies given to Band 1 television channel, thereby allowing subscribers the free choice of ordinary television receivers.

This is one of the reasons why coaxial relay is becoming increasingly popular, particularly with radio traders and manufacturers, as the possibility of monopoly with regard to the sale of television sets is considerably mimimised. Dealer apprehension was born in the early days of sound-only relay when relay companies gained Council concessions, and in addition to supply the sound signals at audio also sold or rented loudspeakers to their subscribers. In effect, this gave the relay company a terminal equipment monopoly and dealers found it increasingly difficult to sell ordinary sets.

Eventually, television on one channel was added to the sound system, and ultimately an additional television channel was added, making a total of two. This later development necessitated extra pairs of conductors. The vision signals on systems of this nature are carried in the region of 3.75 to 28 Mc/s and the sound signals at audio. So-called low-frequency systems of recent vintage, however, can be designed to provide a programme handling capacity of four television (with sound) and four radio, but in this case it is usually necessary to modulate the television sound signals on low-frequency carriers and distribute the radio signals at neat audio. This extended programme

capacity has evolved in essence from the introduction of new multi-conductor cables.

Relay companies distributing signals at low carrier frequencies, as described, are now operating more closely with radio traders than in past years and are allowing them to deal in their terminal units and, in certain cases, they also provide converters to enable ordinary sets to work on their systems.

COAXIAL SYSTEM

Programme capacity does not present much of a problem with coaxial systems, which often work in Band 3, as well as in Bands 1 and 2. This is a good point, bearing in mind that cable installations must have a life of at least ten years to be economic, and it is not always a simple matter to secure permissions for the installation of a second cable. It follows, therefore, that once a good quality coaxial network has been installed, this will be good for all time and permit the distribution of new programmes—colour, toll television, local news items and so on—as and when they become available. It may be necessary, though, to introduce new network equipment or replace existing equipment to keep pace with future trends, but this is relatively inexpensive compared with the erection of a completely new cable network, and new programmes may permit an increased revenue for the relay company. Eighty per cent of the cost of installing a relay is made up of the cable and installation costs.

COAXIAL SYSTEM DEVELOPMENT

Until recent years coaxial systems were viewed as communal aerials, and some supporters of the low-frequency multi-conductor system considered large-scale coaxial distribution with considerable scepticism. Nevertheless, a group of relay engineers worked independently on the various problems involved, and to this work is undoubtedly attributable the highly advanced position held by coaxial relay today.

Possibly one of the first large coaxial relays was that installed in Montreal about 1950. The coaxial cable was aluminium-sheathed and the system distributed two vision carriers, one at 16 Mc/s upper sideband and the other at 28 Mc/s lower sideband. In addition, eight sound programmes were distributed in the spectrum 180 to 340 kc/s.

Following this, several small coaxial systems, employing Band 1 frequencies, were installed in the United Kingdom. These were concentrated in poor reception areas, notably in Wales and the south coast of England. It was during this time that most of the experience concerning the practice of coaxial relay was acquired. New equipment was designed to solve the various problems, and a substantial foundation for coaxial relay was established. Coaxial cables were improved and numerous methods of minimising signal leakage from the cables were developed, including double-screened and taped cables. These are in extensive use today.

EXTENT OF DEVELOPMENT

There was still some debate, however, regarding the area over which a coaxial relay, using signal frequencies, could be developed before deterioration of signal quality halted further expansion. Coaxial networks of several miles were set up with repeaters at intervals to investigate problems of this nature. It appeared that from a practical point of view, having in mind certain limitations, a very large town could be covered with a coaxial system without serious loss in picture quality.

There were several points which had to be observed, however, and these included the method of network planning. There was also shown a definite need for automatic-gain-control to compensate for change in attentuation of coaxial cable with variation in temperature. It was further revealed that the network had to be planned in such a way as to ensure the minimum number of repeaters between the master aerial and the fringe of the network. Some method of resetting the signals of the various channels at intervals throughout a large network was also found essential.

With such factors under control, the first of the large coaxial installations was commenced. The relay system in the City of Oxford is probably the largest coaxial installation in the United Kingdom, and possibly the first of this size ever to be undertaken. Then there is the admirable system at Bath. These are major landmarks in the conquest of coaxial relay, and landmarks which not only reveal that large-scale relay is possible, but also that it is highly desirable and needed by the viewing public. Since the pioneering of these large systems, others have been commenced.

Both the Bath and Oxford systems use what is known as the Band 1 system. That is, all the television programmes, B.B.C. and I.T.A. are given new channels in Band 1, though in certain cases the original Band 1 channel of the B.B.C. may be retained. The systems are thus designed to provide equalised acceptance of the whole of Band 1, from 40 to 70 Mc/s, including repeaters and all other equipment.

There are other arrangements in which systems are designed to accept both Band 1 and 3; and also Band 2, the f.m. radio band. The major disadvantages of such arrangements are the high attenuation of the cables to Band 3 frequencies, and the fact that amplifiers have to be designed to be responsive over a very wide frequency range. Distributed repeaters are employed, which call for the use of twelve valves, as against three or four in a Band 1-only repeater. Nevertheless, such systems are immediately able to accept a multiplicity of programmes without alteration to the network equipment.

Other methods include the distribution of signals at original frequencies, using a repeater for each channel carried. Thus, at each repeater point the signals are separated and fed to their appropriate amplifier. After amplification they are combined and continue their journey together in the coaxial cable, until they reach the next repeater.

FUTURE TRENDS

The changing pattern of television with an increased number of programmes, with colour looming on the horizon and with the possibility of different standards, would all seem to indicate that coaxial relay systems are best suited to cater for these changes most economically, especially from the viewer's point of view. The more complicated off-air reception becomes, the greater the argument in favour of relay, and this is most obvious when viewed against the future multiplicity of programmes.

Sound will be added to coaxial relay systems in the near future. This will be in addition to v.h.f./f.m. distribution at off/air carrier frequencies which is already available to relay operators. Sound in the context meant is a multiplicity of radio and music programmes carried on signals considerably lower in frequency than the television signals.

In order to reap the advantages of such a service, each subscriber will require only a small eight or fourteen channel switch unit, containing a single valve, together with a loud-speaker. One or two of these channels can carry locally derived background music which may be used in Great Britain under certain licence conditions.

There is most certainly a great future ahead for coaxial relay.

CHAPTER TWO

A Survey of Systems

TELEVISION relay in the context to be considered is simply a system of picking up strong and interference-free signals—at a high receiving site just outside a town—and feeding them into the town through cable, where they are then distributed, again by cable, to the viewing public. This apparently simple exercise is loaded with a diversity of problems, many of them very interesting, as we shall see.

One of the earlier systems of TV relay required the conversion of the vision carrier and sidebands to relatively low frequencies, in the region 10-15mc/s, the sound signals being demodulated and distributed as neat audio. Although still in use, this is not a system that can be installed easily by retailers, and will not be considered further.

Distribution at high frequency is now in favour, and systems of this kind are being erected on a progressive scale all over the country by

retailers individually, and in groups, and by other relay concerns.

This method can be divided into three categories, all with one thing in common, which is their suitability for use with any type of standard receiver.

FLATS AND SMALL ESTATES

For small estates and blocks of flats, signals are usually distributed at their broadcast carrier frequencies. Signals in both Band 1 and Band 3 (and sometimes Band 2 signals as well) are picked up by master aerials

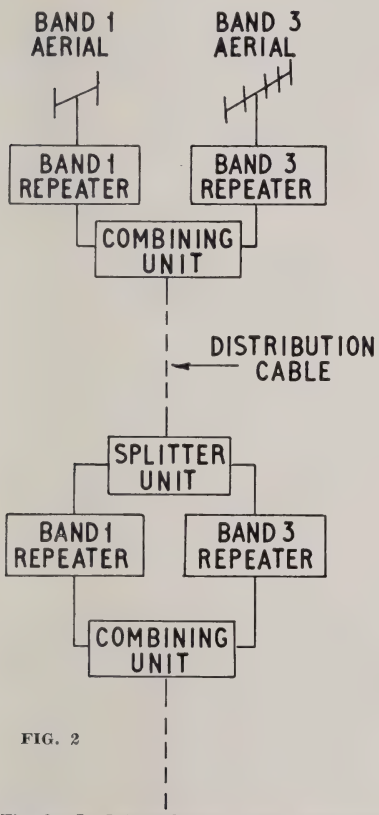


FIG. 2

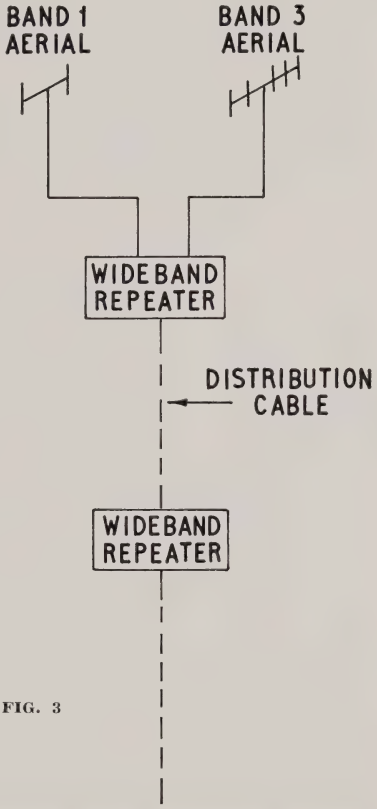


FIG. 3

Fig. 2.—In flats and small estate systems the signals are combined to a common distribution cable. After the signals are weakened by the cable, they are split and again pass through separate amplifiers. They are then once more combined and continue their journey in the cable.

Fig. 3.—In a wideband system, the distribution cable is continued simply by the addition of further wideband amplifiers.

and fed to separate amplifiers, each responsive to one particular channel. The signals are then combined and fed to the distribution cable.

Where the distributed signals are weak, due to the attenuation in the cable, they are split into their channels and again passed through separate amplifiers. In the case of TV, the vision and accompanying sound signals are amplified together, as they are, for example, in an ordinary TV pre-amplifier.

Signals from the different Bands are once more combined and continue their journey in the cable. This process is repeated throughout the network, as shown in Fig. 2.

Instead of separate amplifiers for Bands 1 and 3, dual-band amplifiers or repeaters may be used. These are really two amplifiers in one,

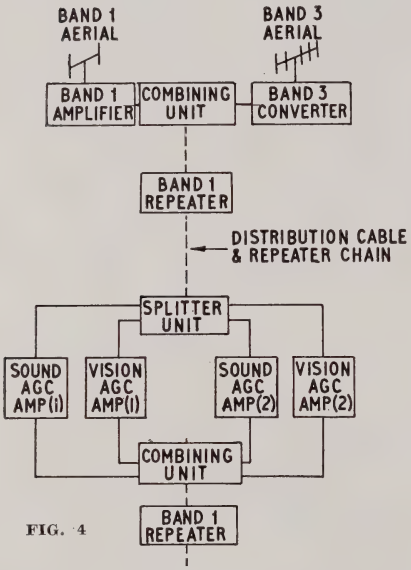


FIG. 4

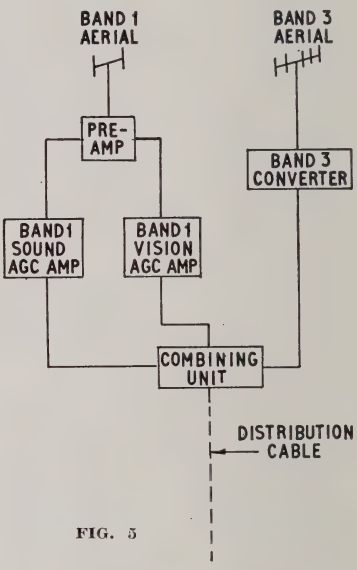


FIG. 5

Fig. 4.—In a Band 1 system (left), all signals are brought to Band 1, and passed through Band 1 repeaters throughout the network. At intervals all sound and vision signals are amplified separately and subjected to AGC and level control.

Fig. 5.—In some Band I systems (right), the Band I sound and vision signals are amplified individually and given AGC before applied to the combining unit.

and they cater for only one Band 1 channel and one Band 3 channel. If Band 2 is required on the system, co-sited Band 2 amplifiers are used.

WIDEBAND TOWN

Where signals are to be distributed over a large area, the simple "flats" system has shortcomings. Refinements such as AGC and signal equalisation become necessary.

One system uses wideband amplifiers called distributed amplifiers, so named not because they have anything to do with signal distribution—this is coincidental—but because the name is that of the circuit

employed. These may have a pass-band from around 40mc/s to the region of 240mc/s.

All the signals for distribution are applied to a single distributed amplifier. As the signal strength falls in the cables, so another wideband amplifier is interposed, and so on (see Fig. 3).

AGC is applied to each repeater through the medium of a pilot carrier sent along the cables with the signals. A method of amplitude equalisation is also adopted to avoid signals of greatly differing frequencies from falling too much out of balance.

To avoid undue attenuation of the high-frequency Band 3 signals, a super-low-loss trunk cable is employed. This is, of necessity, of considerable diameter. The wideband amplifiers are somewhat complex and need to be individually powered.

This system has an advantage in that, if one of the valves in a repeater fails, there is not a total loss of signals, as the system continues working at slightly reduced gain. This is a characteristic of distributed amplifiers, where the valves are effectively in parallel and not in series as with ordinary amplifiers.

BAND I TOWN

An alternative town system reduces all the signal to Band 1 frequencies. The Band 1 signals from the master aerial are themselves applied to a suitable channel amplifier, while the Band 3 signals are applied to converters which change their frequencies to "spare" Band 1 channels. The signals from the Band 1 amplifier and the converters are then combined and fed to the distribution cable.

Signal strength is maintained by small repeaters, responding over the whole of Band 1, interposed at points throughout the cable network.

AGC is not usually applied to the repeaters of this system but, after a certain number of repeaters, all the sound and vision signals are split and passed individually through AGC amplifiers, after which they are combined and fed again to the cable network, as shown in Fig. 4.

The problem of equalising the signals over Band 1 only is not as difficult as equalising over the range of Band 1 and Band 3. Either the repeaters themselves have a rising response or equaliser units are installed at certain points in the network.

Since the Band 3 signals are not distributed at their broadcast frequencies, the cables of this system need not be of super-low-loss type. Thinner cables with an in-built supporting catenary wire are generally adopted.

Power for the Band I repeaters can be applied at low voltage to a few points in the signal-carrying cable network (usually at AGC points), thereby showing a considerable saving in installation costs.

This would appear to be the most popular system with retailers at the present time, possibly owing to the relative ease of installation and remarkable versatility.

The system has several variants, however, such as where: (i) the Band 1 sound and vision signals from the master aerial are sometimes

split and fed to separate sound and vision amplifiers with AGC—see Fig. 5; (ii) the Band 3 converters may convert the sound and vision signals separately; (iii) AGC may be applied to the converted sound and vision signals before they are combined with the other signals; (iv) crystal-controlled oscillators may be used for stabilising the frequency of the converters' output signals.

CHANNEL AVAILABILITY

With high-frequency systems, there is rarely any need to double-up the cable network to put over additional programmes.

The simple "flats" system can be extended in channel capacity by adding amplifiers to suit the new channels. The wideband system caters for all channels, including VHF/FM, over the frequency range of the distributed amplifiers. The Band I system allows the distribution of four television programmes. (Although there are five channels in Band 1, only four are used, Channel 3 being excluded, because of the adjacent channel selectivity limitations of certain commercial receivers which may be connected to the system.)

Band 2 can be added to the Band 3 system by the inclusion of Band 2 amplifiers, which can be co-sited with the Band 1 repeaters in the network.

NEED FOR AGC

Although there is an obvious need for AGC to stabilise the signals as received at the aerials, the reasons for incorporation of AGC in the network itself are not always fully understood.

There are two reasons. First, the attenuation of the network cable is never constant, but varies with temperature. Over long lengths of cable such alteration of attenuation can severely disturb the levels of the signals in the absence of AGC. Over a mile of cable, for example, attenuation could change by as much as 20dB between summer and winter.

Secondly, the use of AGC systems breaks down the repeater network at intervals and allows the correction of signal errors which are likely to arise in repeater chains. Without AGC and level control, a high-frequency system could never be extended over large areas.

EQUALISATION

Equalisation is necessary because the attenuation of cable increases with increase in signal frequency. If this were not corrected throughout a system, the lower frequency signals would soon be at much greater level than the higher frequency signals. In the endeavour to provide high frequency signals at adequate level, the result would be severe overloading of the repeaters by the low frequency signals; non-linearity would produce intermodulation of one signal with another, causing sound-on-vision, vision-on-vision and sound-on-sound.

One method of equalisation makes use of a unit whose attenuation

decreases with increase in frequency, the characteristic opposite to that of the cable. Such units are interposed at intervals in the cable to provide the network with a fairly linear response over the frequency range of the system.

Another method equalises at the repeaters themselves. The repeater response is arranged to rise from the low-frequency end to the high-ferquency end, the slope being adjusted to balance the converse slope of the cable.

CHAPTER THREE

Wayleaves and Planning

AFTER a wiring concession has been granted for a town or an estate, the installation of a relay system does not consist only of the planning of the system on a map, followed by the erection of cables and repeaters in accordance with the plan. There are numerous other factors which need attention before wiring can be started or a working plan evolved.

A wiring concession granted by a local authority usually extends to the erection of cables on all property owned by the authority or council. However, it does not endow the relay company with the right to erect cables or equipment on privately owned property; neither does it provide full clearance for the erection of aerial masts, aerial stations and control stations.

Permission to erect cables and equipment on private property can be secured only from the property owners. Erection of aerial masts and buildings to house the associated equipment, even if on council property, must have planning approval. Also, it is usually necessary to obtain permission from the appropriate authority to install cables overhead; especially over roads, for which there are various local stipulations with regard to cable height, method of attachment, etc.

SITING POLES

Special permissions have to be sought for routing cable underground, beneath roads, in culverts under roads and railways, under bridges, under and over streams and rivers, etc.

The siting of poles comes under the watchful eye of the planning authority. Poles should be avoided as far as possible, and where long tracks of trunk cable are required careful thought should be given to putting these underground. It weighs greatly against a relay company if large sections of cable are routed overhead, especially now that it is the policy of the Electricity Authority and Post Office to lay cables underground. It is vital that a relay system ultimately serves to enhance the amenities.

Before it is possible to settle down and plan a system, all the initial wayleave permissions must be obtained (wayleave, as the word implies, is freedom or *leave* to use a particular *way* or path). A system usually starts off with the aerial mast, the aerial station and the cable run linking the aerial station to the first point of distribution.

FIRST AREA COVERAGE

When the site for the aerial and its station has been decided, the next move is to establish the first area to be covered by the distribution network. Economically, this is invariably a fairly heavily populated area as close as possible to the aerial site. However, it must be remembered that houses in close proximity to the aerial will nearly always be in a relatively high signal field, and that viewers therein may obtain good direct signals. If, however, the ground falls away rapidly from the aerial site, and the houses at the base are badly shielded from the transmitter, this represents the ideal relay situation.

When both the aerial site and the first distribution point have been established, the area between should be surveyed and a tentative plan drawn up for the installation of the cable section and repeaters. The final working plan will be governed entirely by the availability of wayleaves on the cable route, and the theoretical plan will depend on the type of equipment used.

DELICATE BALANCE

One cannot generalise on these matters, but it is essential that the shortest possible route be obtained for the cable and that the system be planned in strict accordance with the instructions issued by the planning company or by the manufacturer of the equipment.

The network as a whole, including cable and repeaters, has to be delicately balanced in terms of losses and gains over the operating frequency band (and this may not be fully exploited at the time that the system is first installed). If one section is somewhat out of balance, it is not a simple matter to restore overall balance by purposely unbalancing another section to compensate. Although it may work over a limited area, this practice is deprecated, and the relay operator who adopts it will soon find himself in trouble as his network grows.

The aerial site should be at the highest possible altitude consistent with being sufficiently near to the town or first distribution point to facilitate the installation of the primary cable run. The site should be well clear of roads, high-tension cables and machinery which would be

likely to cause interference. It should be in a high signal field of the nearest or most easily received ITA and BBC TV and VHF-FM stations. If there is information of a projected new station to cover the area in the near future, the proposed position of this must also be taken into account.

There should be reasonable all-weather access for vehicles, and a sufficiently large area to erect a tower and build an aerial station. Electricity should be available.

Before the site is finally adopted, the signal strength from the transmitters it is proposed to use should be recorded daily over the course of several weeks, and the programmes should be monitored on a television receiver to check for interference. A collapsible mast and a caravan are useful for this rather formidable, though necessary, exercise. Electricity can either be generated on site (ensuring that the plant is adequately suppressed) or a temporary mains line installed.

The minimum signal (as induced in the aerials) that can be tolerated on a relay depends very much on the type of equipment employed. At least 1mV should be sought on all channels. Often this is not available on Band 3, however, but here a good low-noise mast-head amplifier may allow the use of a signal as low as 50 microvolts, provided it is not too variable.

A low initial test signal should not lead to the site being abandoned without further tests, for it is surprising how much more signal can be collected on a properly-installed, high-gain array. However, this should not be taken to mean that an increase in aerial height is always accompanied by an increase in signal, as there are occasions when the aerial signal is actually reduced by an increase in height.

It is usual practice to route a virgin cable (unloaded cable) from the aerial station to the first distribution point, and from there arrange the network cables in the form of spokes on a wheel to provide optimum coverage.

There are several ideas on this, but a very satisfactory scheme is to make the distribution point on AGC and monitor station. Here the levels can easily be reset to compensate for any unbalance which may have occurred on the virgin cable before the signals are fed to subscribers. This also allows a check to be kept on the quality of the signals.

NEAR TO CENTRE

In relatively small installations, it is a good idea to site the distribution point as near to the centre of the town as possible. This enables the distribution cables to be kept short and makes it less difficult to achieve wayleave continuity on any outgoing cable.

In large installations, several distribution points will have to be centred in areas of high population and linked together either by virgin cable or cable which is very lightly loaded. In other words, the interconnecting cables should not feed subscribers direct, though they could be used to feed spur cables to which subscribers are connected. The two conditions are shown in Fig. 6.

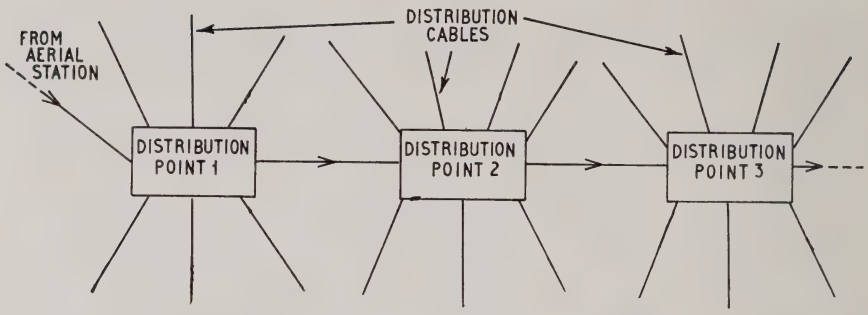


FIG. 6

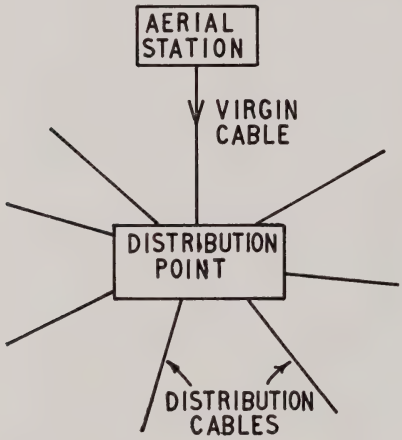


Fig. 6.—In a small installation, one centrally-placed distribution point may be sufficient to feed the town (left). Larger installations may require several inter-connected distribution points above.

Such inter-connecting cables constitute a trunk line which threads its way through a town. After the wayleaves for the aerial staion and the first distribution point have been obtained, attention should immediately be directed towards securing wayleaves on the proposed trunk route and the first distribution area. If the first area is a council estate, wiring can usually be commenced here while the larger items of relay equipment are being installed.

Even when permission to wire a council estate is granted, each tenant should be contacted by the relay company before house wiring is started. This goes a long way towards creating good feeling between council tenants and the relay company, which is highly important, especially during the launching of a relay.

The long-term success of a relay depends on the quality of signals distributed and on the number of programmes provided. It is surprising how quickly a viewer becomes accustomed to interference-free reception from a relay after he has abandoned his aerials. He becomes highly critical of reception at a far higher standard than hitherto, and it is vital that this high standard be maintained.

It is also essential that the relay be capable of catering for any programmes promised for the future. Large installations may take two or three years to complete, and it would be most disturbing, to say the least, to find that programmes launched at that time could not be relayed.

CHAPTER FOUR

The Aerial Station

THE aerial site must not be too far away from the town since, in a large system, the primary cable from the aerials to the first distribution point is really dead cable, and should not be used to feed subscribers direct.

Signals on the required channels should be strong and free from impulsive. RF. radar and multipath interference. Mains power should be at hand, or at least within reasonable cabling distance from the site if mains-operated equipment is to be used at the aerial station. Reasonable access for motor vehicles should be available, having in mind maintenance problems during bad weather.

An average run of primary cable is, perhaps, in the region of 500 to 1,000 yards long, but this length may well be exceeded in large systems where the only high ground is some distance from the nearest built-up area in which can be sited the first distribution point. In some relay systems the aerials are almost 1½ miles from the nearest distribution point, and several repeaters are used along the primary cable to equalise the losses and maintain the signal level. These are key repeaters on which the satisfactory operation of the whole system depends.

STANDBY EQUIPMENT

Where it is necessary to employ an extended primary cable of this nature, standby primary cable, primary repeaters and aerial station equipment are desirable. It should be possible to control these remotely from the first distribution point, where there may also be monitoring equipment, so as to ensure continuity of service in the event of failure of the main equipment.

Standby equipment avoids lengthy breaks in service and allows leisurely maintenance of the faulty equipment.

In small installations the aerial site is often within easy reach of the town with a short primary cable, and standby plant may not be warranted. Moreover, there is often no need to use extensive aerial station equipment in the smaller system; indeed, an aerial station may not even be necessary, as will be discussed later.

AERIALS AND SIGNALS

There are several types of aerial tower from which a choice can be made. The most popular appears to be the self-supporting type made from mild-steel tubing and of triangular cross-section. This is available from 40 to over 100ft. in height.

A mock-up mast carrying a double-six Band 3 array and a two-or three-element Band 1 array will give a good idea of the signals to be expected when the aerials are permanently erected.

Usually, it is not difficult to obtain at least 1mV from the local BBC station, and a signal below this value should not normally be considered. Even towards the fringe of the BBC service area, a double-three array, correctly matched, at a height of about 60ft. should provide a signal of that strength at most good sites on high ground (400-500ft.).

On Band 3, the problem may be more difficult and a weaker signal has often to be tolerated. Nevertheless, around 100 microvolts is usually obtainable in the most difficult places by the use of a good array.

Towards the fringe of the ITA service areas four nine-element aerials correctly matched and spaced in a "box array" may be required. However, in most cases a double-six array at a height of about 60ft. above ground provides adequate pick-up from the local station. It is encouraging to know that a good high-gain low-noise masthead amplifier permits an aerial signal as low as 50 microvolts to be workable from the relay angle.

One can be assured, of course, that such a low signal on a high contour indicates that the town is virtually without signal. At a good site two or more workable ITA programmes may be received. At an overall height in the region of 600ft., Band 3 signals from a station about 100 miles distant can often be received provided there is no undue obstruction between the transmitting and receiving aerials. Unfortunately, at this distance, fading is invariably troublesome due to tropospheric effects, but this can be smoothed out with AGC at the converter and at the masthead amplifier.

It is difficult to generalise about the minimum aerial signal required to provide satisfactory distribution, but in all cases the signal strength and the signal-to-interference ratio at the site will show a vast improvement over the town. Nevertheless, every endeavour should be made to secure the best possible signals, for a good input goes a long way in masking the inevitably shortcomings of distribution over long cable networks.

DISTRIBUTION CHANNELS

In a Band 1 system, the Band 3 signal is converted to an "unused" channel in Band 1, and the Band 1 signal itself may or may not be converted to a new channel. Band 1 conversion depends primarily on channel availability within the pattern of channels selected for the system As it is necessary to take into account the adjacent channel selectivity limitations of receivers likely to be connected to the system, all the five Band 1 channels cannot be used.

Some relay equipment manufacturers recommend the use of alternative channels—e.g., Channels 1, 3 and 5. However, it is possible to accommodate four channels without ill effects by displacing one or two of the channels slightly. Channels 1, 2, $3\frac{1}{2}$ and 5 or 1, 2, 4 (minus 1mc/s) and 5 (plus 1mc/s) are patterns which are used in practice.

With the four-channel arrangement, the natural spacing between Channels 1 and 2 is sufficient, having in mind that this spacing (3.25 mc/s) is greater than the spacing (1.5mc/s) between the other adjacent channels, owing to the fact that Channel 1 at one time accommodated a double sideband vision signal.

RADIATION

There is a reason why it is sometimes desirable to avoid the use of the received channel for distribution. All relay networks radiate to a degree dependent on the radiation factor of the cable itself and on the amount of mismatch introduced into the network by the connection of spur and subscriber tap-offs.

The greater the mismatch the greater the radiation from the cable, and this applies even if the cable itself is virtually radiation free. This does not imply that the radiation factor of the cable is unimportant; indeed, the amount of radiation from a poor cable is far greater than that from a good cable loaded in the same way. This will be dealt with in greater detail in a subsequent chapter.

In an area of relatively high signal field small radiation from a cable will have no effect on pictures obtained from adjacent aerials in the ordinary way. But in an area of low signal field, even the smallest signal picked up from the cable by the aerials of non-subscribers will almost certainly produce a double image if on the same frequency as the "off air" signal. To avoid this problem a channel change is usually recommended.

The reciprocal of this problem may occur in an area of very strong signal field from a local TV station. Then a channel change is recommended to avoid interference by signal picked up on the cable with the signal being distributed.

With a wideband system, the same problems exist on Band 3 as well as on Band 1, and conversion of Band 3 channels may be required.

AERIAL STATION EQUIPMENT

A hypothetical aerial station is given in block diagram in Fig. 7. This represents a Band 1 system where three ITA programmes, one

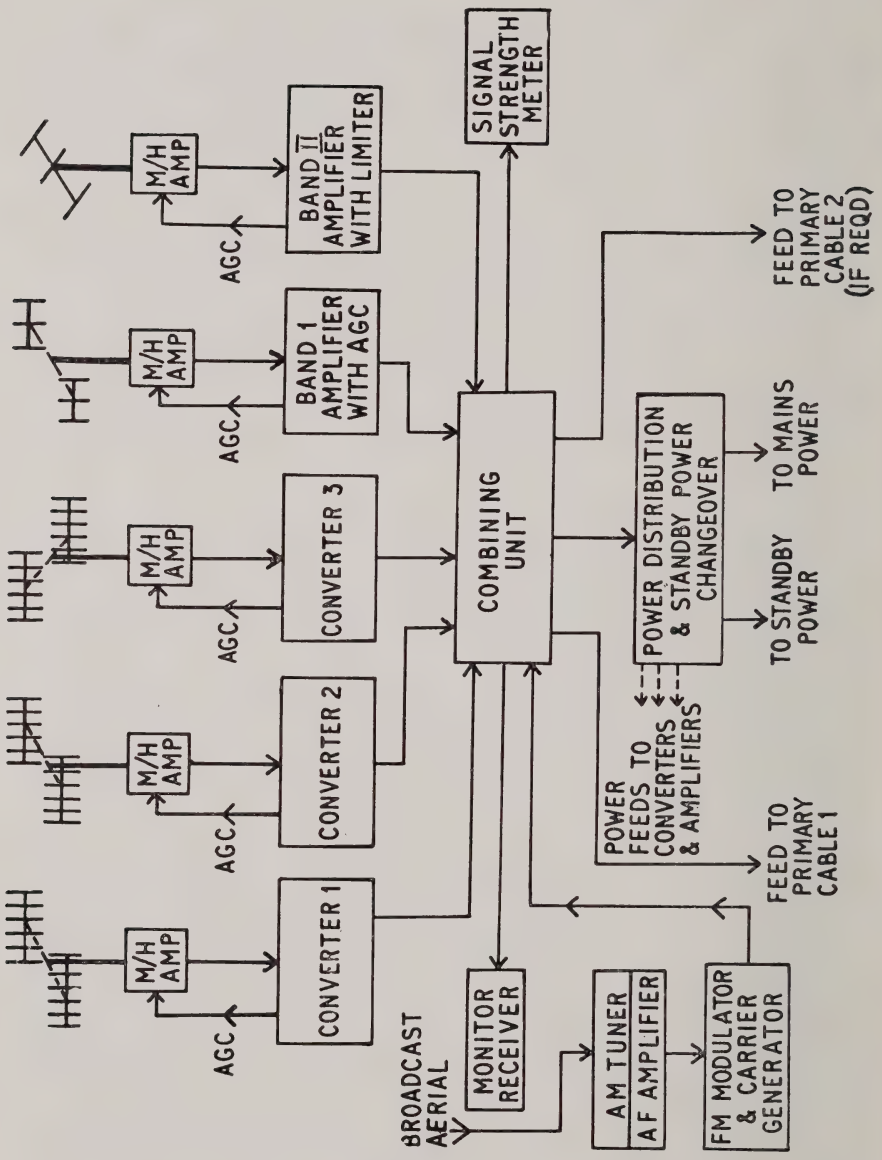


FIG. 7

Fig. 7.—Block diagram of a hypothetical aerial station in which three ITA programmes, one BBC and one VHF/FM are converted for use on Band 1 distribution system.

BBC programme and the VHF service are available at the site.

Three converters change the Band 3 signals to Band 1 channels. It is supposed, in this example that the BBC programme can be distributed at received carrier—the local Band 1 channel being available in the make-up of the four distribution channels. For example, Channel 1 may be distribution "neat," and the three commercial programmes changed to Channel 2, 4 (minus 1ms/s) and 5 (plus 1mc/s).

This arrangement would be used only if the local BBC field strength were strong enough to mask small network radiation but not so strong as to give interference on the system due to pick-up on the cables. Otherwise, a converter would be used to change the BBC channel, and it would be desirable not to use the local Band 1 channel but to employ the four "unused' channels for distribution, if possible.

For FM, a Band 2 amplifier with amplitude limiting is used, the output being mixed with the signals from the other amplifier and converters, in the combining unit, which feeds them all to the primary cable/s.

To preserve a high signal-noise ratio, and to lift the aerial signals to a suitable level for applying to the amplifiers and converters, a masthead amplifier is indicated at each aerial, and each one is controlled by an AGC bias produced in the associated converter or amplifier. This not only minimises fading but helps to avoid overloading in the event of the aerial signal rising to an abnormally high level—which sometimes happens in fringe areas.

The combining unit feeds a monitor receiver and signal strength meter to allow a check to be kept on picture quality and the signal strength on all channels fed to the primary cable.

The power distribution and standby power changeover unit feeds power to the various pieces of equipment from either the local mains supply or a standby power source. In the event of failure of the local mains changeover relays operate and switch on the standby power plant. The unit may also serve to switch the station equipment on and off remotely by reason of a low voltage applied to, or removed from, the primary cable at the first distribution point. Two complete sets of equipment would allow either one or the other to be switched remotely in the event of a fault.

The power unit may, in addition, provide a low voltage for powering the masthead amplifiers via the signal-carrying downleads and low-pass filters, such as shown in Fig. 8.

SMALL SYSTEMS

In addition to the three BBC FM programmes, a fourth Band 2 FM carrier can be introduced to the system, and may be modulated by programme material (AF) originated from either wire or a broadcast receiver.

In a small system, all equipment, excluding the masthead amplifiers, can be housed at the first distribution point, where a low voltage can be fed into the cable, via power filters, to power the remote mastheads.

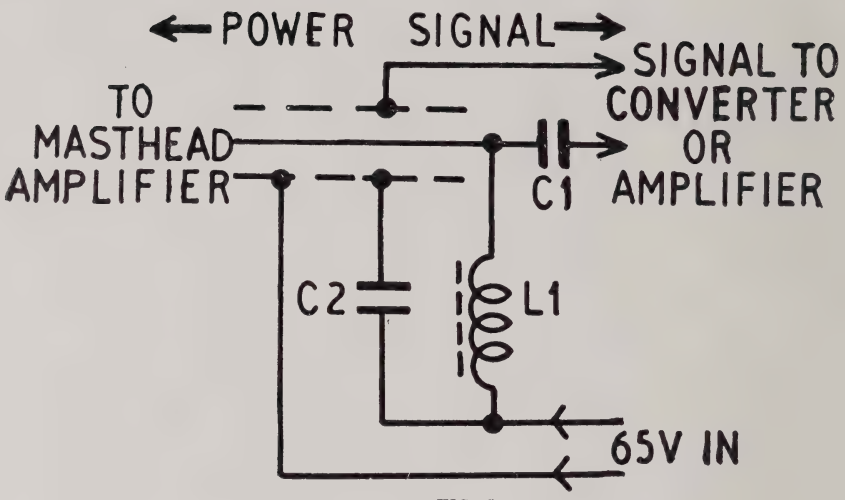


FIG. 8

Fig. 8.—Low-pass filter enabling the signal to pass to converter or amplifier without interruption while power for the masthead amplifier is fed in the opposite direction—all in a single coaxial cable.

Filters would then be used to combine the signals from the mastheads to a single cable to the amplifier/distribution point. Aerial station equipment will be described in greater detail in a subsequent chapter.

CHAPTER FIVE

A Typical Coaxial System

IT is not proposed to describe the various pieces of equipment now available for coaxial relay; such information is gladly given to all interested firms and engineers by the manufacturers. It is intended to give a bird's-eye picture of a typical system primarily in terms of the basic equipment required. Fundamental operation will be described, and the signals followed from the aerials to the subscribers.

Chapter 4 gave the broad outline of the aerial station. Here the aerial signals are amplified by masthead amplifiers positioned as close as possible to the aerials to obtain the best signal-to-noise ratio. Unless the aerial signal is exceptionally high, a masthead is employed for each composite sound and vision channel received.

EXCEPTIONAL CASES

In exceptional cases, where selective fading is troublesome, separate amplifiers may be used for sound and vision and each given independent AGC. The amplified signals are then fed to 'same channel' amplifiers and/or channel converters, after which they are combined and fed to the primary cable.

Masthead amplifiers—sometimes called pre-amplifiers or head amplifiers—may feature one, two or three stages and have an overall gain between 10 and 40dB, depending on requirements and signal conditions. In most units are some arrangements for adjusting the gain to suit the following amplifiers or converters.

Low-noise circuits are adopted, with cascode or grounded-grid input stage, followed by further cascode or pentode stages. Each amplifier should be able to deliver at least 250mV of both sound and vision signal without non-linearity. This is important, since non-linearity is the main source of intermodulation of the two signals, giving sound-on-vision and vision-on-sound. Avoiding non-linearity in relay is a major problem, as will be seen in following chapters.

In addition to providing the best signal-to-noise ratio at the beginning of a system, the mastheads also serve to raise the aerial signals to a suitable level for applying to the converters and/or same channel amplifiers. The bandwidth and response should embrace both sound and vision signals without introducing distortion, and should have a fairly reasonable cut-off outside the channel to avoid interaction due to adjacent channel signals likely to be received at high strength at a good aerial site.

Owing to the difficulty of feeding mains power to the top of the aerial tower, mastheads are often designed to work from a low AC voltage (not exceeding 65VRMS). This is applied at the aerial station, via filters, to the signal carrying downleads, and is filtered again at the masthead power unit (see Fig. 9).

It is not usually desirable to operate the mastheads at maximum output owing to the possibility of overloading in the event of an increase in aerial signal. In some cases this cannot be avoided since where the average aerial signal is low, the maximum gain of the masthead must of necessity be fully exploited.

Under such a condition, particularly where the signal is subject to variation, some form of masthead AGC is required. This is not only to assist in avoiding over-loading the masthead, but also to prevent the masthead output signal rising to a level that would be likely to run the same channel amplifier or converter into non-linearity.

The usual method is to pick up the control bias from the AGC

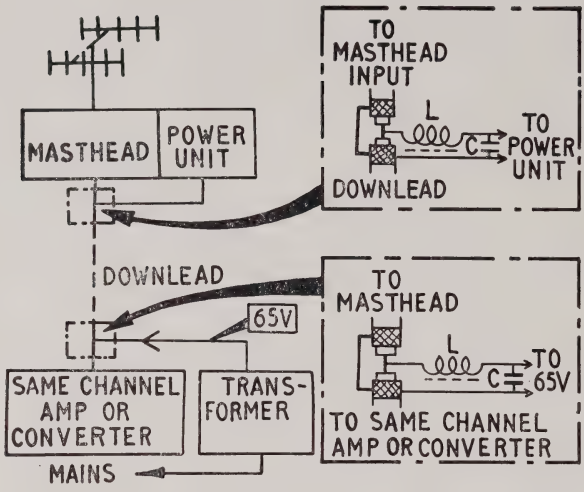


FIG 9

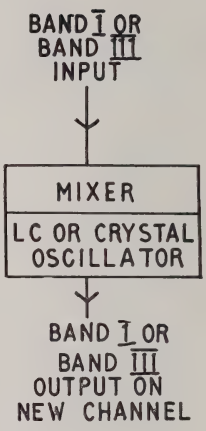


FIG. 10

Fig. 9.—The method of feeding power through the downlead to energise the masthead amplifier.

Fig. 10.—A simple channel converter.

circuits of the associated same channel amplifier or converter and feed it to the masthead through a separate cable or through the signal carrying downlead, via suitable filters. In the latter case, the downlead could not also be used to carry power to the masthead, but one of the downleads associated with a masthead not requiring AGC could be used to carry power to the other AGC mastheads or, alternatively, a separate low-voltage cable could be installed exclusively for carrying the power.

Either the AGC associated with the vision signal or an average of sound-and-vision AGC is used on a composite sound and vision masthead. Where separate sound and vision mastheads are adopted, however, each receives its own AGC from the station equipment; this being necessary, of course, to help combat selective fading.

CONVERTERS

Converters for coaxial relay range from the simple single-stage frequency changer (Fig. 10) to the more elaborate arrangements of Figs. 11 and 12. The two chief requirements are freedom from frequency drift and freedom from spurious output signals.

In Fig. 10 the input signals are converted to a new channel (sound and vision together), and the circuitry is much the same as that used in ordinary receivers, although, perhaps, the frequency stability is improved, either by positive and negative temperature co-efficient tuned circuit elements in correct proportion or by the use of a crystal.

In Fig. 11 two frequency-changer stages are used, one following an

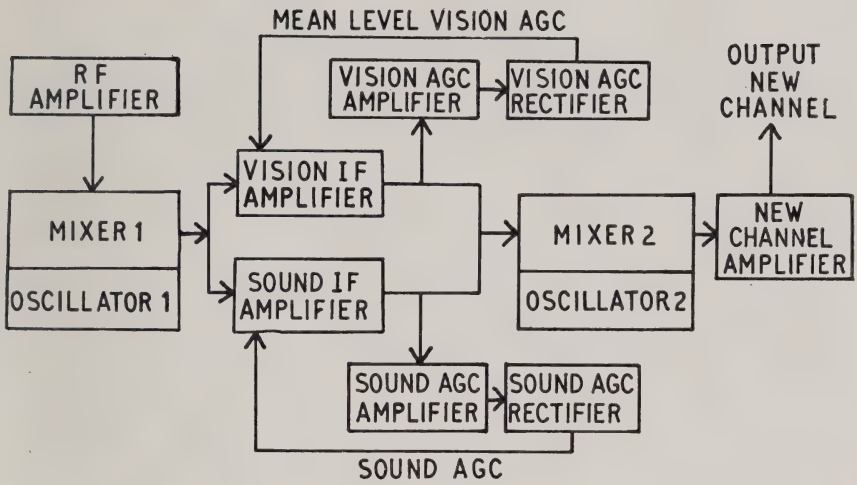


FIG. 11

Fig. 11.—A more elaborate arrangement where two frequency changers are used and sound and vision signals are amplified at IF.

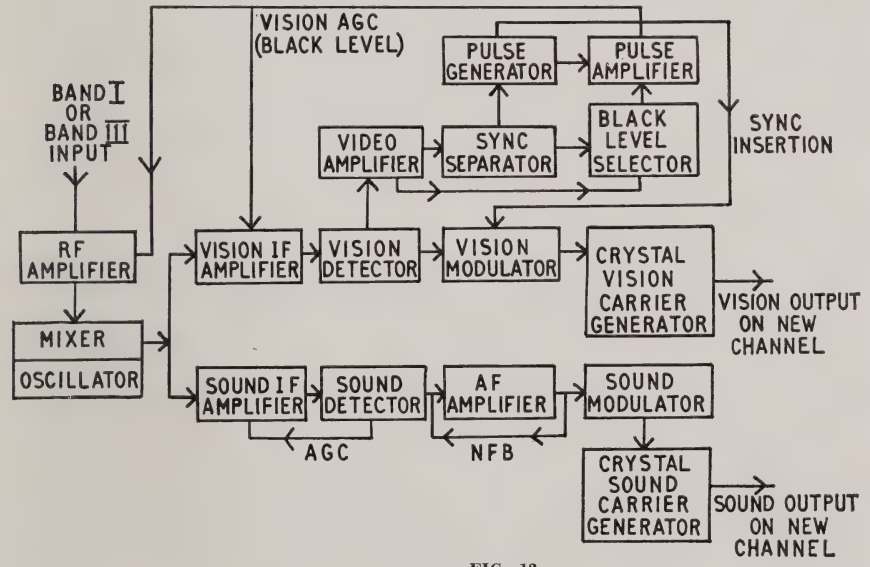


FIG. 12

Fig. 12.—In this converter the sound and vision signals from the frequency changer are amplified at IF, demodulated and then used to modulate crystal-controlled sound and vision generators at the new output frequency.

Fig. 13.—Output frequency stability is sometimes enhanced by the use of a crystal oscillator and frequency doubler. When this is used, the original oscillator becomes oscillator amplifier.

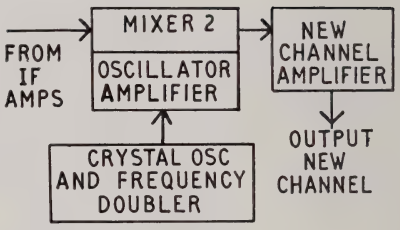


FIG. 13

RF amplifier, which gives sound and vision signals at IF, and the other converting the IF signals to the new channel frequencies and then passing them to a new-channel amplifier.

Vision and sound AGC is introduced in the IF amplifier stages, and in this type of unit it is often the mean level of the vision signal which is derived as the control bias. Fig. 13 shows how the output frequency may be stabilised by means of a crystal oscillator and frequency doubler. When this is used, the original oscillator becomes an oscillator amplifier.

MORE ELABORATE

Fig. 12 shows a block diagram of an even more elaborate arrangement. Here one frequency changer receives signals from an RF amplifier and produces sound and vision IF signals. Each is amplified and demodulated and the resultant video and audio are used to modulate crystal-controlled vision carrier and sound carrier generators at frequencies corresponding to the required new channels. There are also various intermediate circuits for producing pulse-amplified black level vision AGC, black level clamping, sync pulse reinsertion, etc. This is a rather specialised piece of equipment, which is really a sound and vision receiver/transmitter all in one, and is highly desirable where a large number of subscribers are tied to a common aerial, to ensure that the signal starts off right and is utterly free from spurious signals.

Most elaborate converters have facilities for measuring and adjusting the various signals by means of a meter movement, rotary switch, level controls and other adjustments. These ensure that the unit is accurately set-up and speed daily or weekly tests without disturbing an operative system. Some also feature a turret front-end which allows a rapid change to any input frequency in Bands 1 and 3.

SAME CHANNEL AMPLIFIERS

The same channel amplifier is used instead of a converter when it is required to distribute Band 1 signals at natural carrier frequencies. There are two basic versions: one which uses separate sound and vision amplifiers, and another which uses one amplifier common to both sound and vision.

The two-amplifier version has much to commend it since AGC can be applied separately to the sound and vision channels and the signal

levels to primary cable can be set independently. Moreover, black-level vision AGC is possible only with this arrangement.

WIDE BAND SYSTEM

With the wide band system, the set-up is much the same as already described. A masthead amplifier is used for each channel, and each feeds into its own control amplifier. Converters may not be used, however, as all the signals are usually distributed at natural carrier frequencies, unless it is necessary to convert a channel to avoid interference troubles or to allow all the stations to be comfortably accommodated in the bands without imposing on the selectivity limitations of receivers connected to the system.

The control amplifiers in this system are common to both the sound and vision signals, and AGC from these is fed back to the mastheads.

VHF-FM

For distribution of the VHF-FM signals of the BBC a set of aerial station equipment embracing the whole of Band 2 is required. This includes Band 2 aerial, masthead amplifier and same channel amplifier or control amplifier.

In addition to the BBC VHF-FM signals which are distributed at natural frequency to operate any standard FM set or TV set with FM, an independent FM channel may be added to the system. The VHF carrier is produced by an oscillator at the aerial station at a frequency which falls in a clear spot in Band 2. This carrier is frequency modulated by the required audio signal.

The independent FM channel is usually arranged to carry Radio Luxembourg, so that subscribers on the system have, in addition to the television programmes, a choice of the three BBC programmes plus Radio Luxembourg; provided they have an FM set, of course.

COMBINING SIGNALS

The signals at distribution frequencies appearing at the output of the converters, the FM oscillator and same channel amplifiers or control amplifiers are combined and then fed through the primary cable into the first distribution area.

The combining is either accomplished in a match resistive network or by means of a coaxial transformer. In either case, however, losses are incurred in the combining process, so the signal levels at the output of the various pieces of equipment feeding the mixer should be high enough to allow for these losses.

At intervals, depending on the attenuation of the primary cable repeater, amplifiers are interposed along the primary route. In a wide band system, each repeater caters for the Band 1, Band 2 and Band 3 signals, while in a Band 1 system two co-sited repeaters are required, one for the television signals and another for the FM. Nevertheless, a common power pack supplies both FM and TV repeater strips, and the

total number of valves used per repeater system is usually less in the Band 1/FM system than in the wideband system.

To maintain all the signals at the same level at the input to each repeater, some form of equalisation is essential owing to the increase in cable loss with increase in frequency.

There are two ways of achieving this. One by giving the repeaters a response which rises with frequency, and starting the signals off at the aerial station with a progressive increase in level from the low to the high frequency channels; the other by introducing equalisers at the input to each repeater and starting the signals off all at the same level.

The equalisers serve to attenuate the lower frequency signals and reduce them to the level of the higher frequency signals, and in this way each repeater has an input over the whole of the band which is susbtantially flat. Both arrangements are used in practice.

Where several signals are carried in one amplifier non-linearity becomes even more important to avoid intermodulation, and without adequate equalisation the lower frequency signals would soon reach a level that would overload the amplifiers. Intermodulation does not occur in the cables, but only in the electronic equipment associated with them.

CHAPTER SIX

AGC: System Distribution and Powering

THE sound and vision programme signals fed to the primary cable from the aerial station are maintained at a suitable level by repeater amplifiers spaced at intervals along the cable. This process is usually continued, as required by the length of cable, to the first point of distribution.

In most large installations, each distribution point represents an AGC System.

Although AGC is applied to the source equipment at the aerial station, further AGC in the network is necessary to counteract any variation in attenuation of the cable which can occur due to change in temperature.

It is desirable to apply AGC to each signal on the network, and to accomplish this it is necessary, first, to separate the signals and feed them individually to AGC amplifiers.

With some systems, simple splitting of the channels carrying both sound and vision signals is employed, but with other systems each sound and each vision signal is amplified and given AGC independently. This latter method is often preferred since it avoids interaction on the sound channel, for instance, in the event of a signal reduction on the vision channel, and vice versa. The two methods are represented in Figs. 14 and 15.

The AGC distribution point also serves two other purposes. First, it allows each sound and each vision signal to be adjusted to the correct level for applying to the distribution cables and, second, it represents a convenient point for introducing a low voltage into the distribution cables for powering the repeaters in the network.

'LINE POWERING'

When repeaters are so powered, the term "line powering" is used. This is a very economical arrangement, of course, as it avoids a mains power connection at each repeater. With line powering, at least ten repeaters can usually be energised power-wise from one AGC System. There is no difficulty, however, in energising a greater number of re-

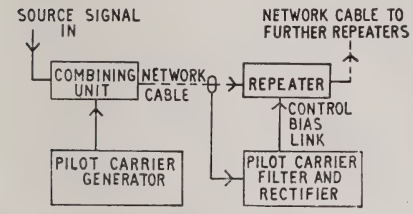


FIG. 14

Fig. 14.—AGC amplifiers carrying both sound and vision for each channel.

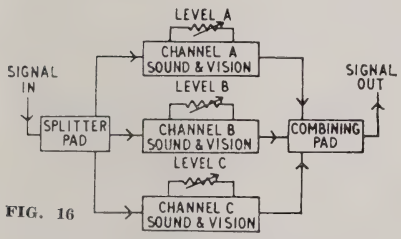


FIG. 16

Fig. 16.—Block diagram showing the pilot carrier method of network AGC. The pilot carrier is filtered and rectified at certain main repeaters and then utilised as a control bias.

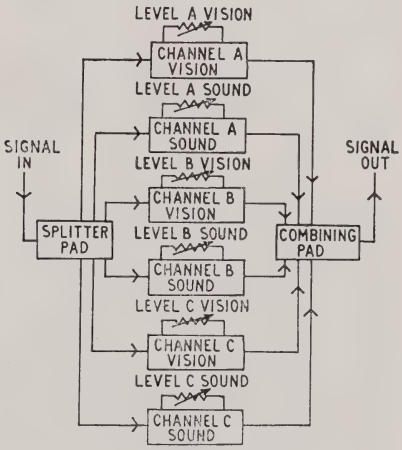


FIG. 15

Fig. 15.—Independent level adjustment to each sound and each vision signal is provided by using separate sound and vision AGC amplifiers.

peaters from one AGC System, thereby showing a considerable saving in installation costs.

Where the AGC System caters for each sound and each vision signal, the levels of the signals on all channels can be set accurately to suit the subsequent cable network and to facilitate equalisation over any length of cable.

A similar arrangement can be utilised when the network signals are simply divided into sound plus vision channels but, with this arrangement, level adjustment of one channel will affect both sound and vision signals, and it is possible only to equalise on the channels carried in terms of frequency versus cable attenuation. This means that an adjustment to the level of the vision signal will give a corresponding increase or decrease to the sound signal.

This arrangement, of course, does not allow for correction between the levels of associated sound and vision signals, which is often necessary in practice due to inevitable small mismatches on the cable network.

It must at this stage be fully appreciated that any relay system is solely a compromise in matching. The aim, of course, is to secure the best match possible under conditions which can never be, technically, exact.

In both cases signal level adjustment is provided by a level control on each AGC amplifier. Following amplification of each channel or each sound and vision signal the signals are combined in a matched pad and then applied to subsequent distribution cable, as shown in Figs. 14 and 15.

PILOT CARRIER

Another method of obtaining network AGC is by means of a pilot-carrier. Here an oscillator working at a frequency outside the distribution frequencies applies a signal to the whole of the cable network at the aerial station. The signal is filtered at certain repeaters and is rectified so as to produce a negative voltage. This voltage is applied to certain controlled valves in the repeaters exactly the same as AGC bias is applied to the controlled valves in television and radio sets. In the event of an increase in attenuation of the network cable the amplitude of the pilot signal will decrease and the AGC bias of the repeaters in the affected network will also decrease, thereby causing an increase in gain which automatically cancels the increase in attenuation of the cable. This arrangement has several desirable features, but it allows neither independent adjustment to the network signals nor the introduction of line power. A block diagram of the method is given in Fig. 16.

Small systems feeding a dozen or so houses on a little estate or a block of flats are not absolutely dependent on network AGC, since the cable lengths used are hardly sufficient to deviate severely from their nominal attenuation owing to temperature change or other causes. Nevertheless, AGC at the source equipment should be investigated if the system is to operate in a fringe area where there is likely to be fluctuation in received signal.

Large systems using thousands of yards of cable could never work properly without network AGC. If the system is correctly set up for signal level under one condition, a gradual decrease in temperature of the inter-repeater cables could cause a progressive rise in signal level over the whole system. While this may be adequately handled by the AGC on subscribers' receivers, there is always the possibility that repeaters would overload due to too strong an input signal.

VISION AGC

There are two types of vision AGC used in relay equipment. One is the mean-level type in which the amplitude of the vision signal is averaged to provide a negative control bias, while the other works on the black-level of the vision signal. Both are used in television receivers, and the merits and demerits apply to relay as in a television set.

The mean-level suffers from the disadvantage that marked changes in video modulation result in changes in gain of the AGC amplifiers. This is completely avoided by the use of the black-level arrangement, in which the black-level of the video signal is sampled or gated and then rectified to give a negative control bias. The black-level, of course, is unaffected by changes in video modulation.

A black-level vision AGC System used by one relay equipment manufacturer utilises a pulse amplifier circuit. A pulse generator, which may or may not be locked to the line frequency, powers a pulse amplifier whose input signal comprises the composite vision signal and the sync pulses only of the same signal in suitable phase. In the event of signal variation the input of the pulse amplifier sees only a variation in the black-level datum of the composite signal. This results in decreasing or increasing conduction of the amplifier, which is reflected in the output circuit as an increase or decrease in AGC bias.

CAN BE DIVIDED

In all systems, sound AGC usually follows the arrangement found in most radio sets.

One advantage of the use of AGC Systems is that a large relay system can be divided into several small systems, each section containing one AGC System to serve the associated area.

An extended installation of this nature is shown in Fig. 17. It is seen that each AGC System feeds several spur or subsidiary trunk cables to embrace fully the area involved. These cables themselves feed either subscribers direct or subscriber spur cables, via repeaters when necessary, as shown in Fig. 18.

The first AGC System receives its signals from the aerial station through the primary cable, while subsequent AGC Systems are interlinked through trunk cable, which is maintained as free as possible from loading of any kind. In this way each service area is under the direct control of an AGC System, at which point the signals may be monitored for quality and strength.

WIDE-BAND DRAWBACK

With low-loss cable, the trunk on a Band 1 installation may extend up to one mile without the use of repeaters, but on wide-band systems the greater attenuation of the cable at the higher distribution frequencies, coupled with the lower gain of the repeaters compared with Band 1-only repeaters, demands the use of more than twice as many repeaters over a cable of given length and type. Unfortunately, this is one of the costs of maintaining a large number of distribution channels.

On spur cables this does not apply to such an extent, since a large proportion of the total attenuation of the network is made up of spur couplings and subscribers' tap-offs. In Fig. 18 is shown the distribution system within an AGC System service area in greater detail.

When this method of AGC distribution is adopted, the only power supply source for the whole area can be established at the AGC System itself. On each trunk and subsidiary trunk emanating from the AGC a low voltage can be applied, in addition to the signals, for powering the repeaters over the entire network. Each repeater would then have

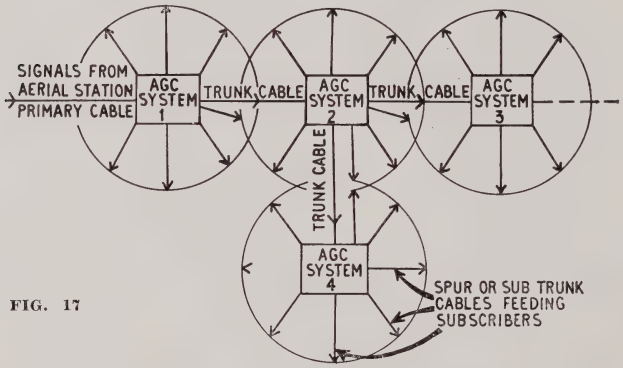


FIG. 17

Fig. 17—Large relay systems can be advantageously divided into several small systems, each section containing one AGC System to serve the associated service area.

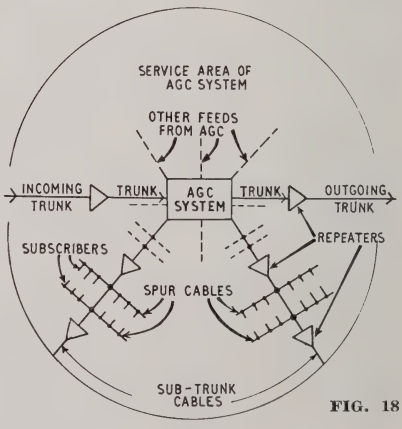


FIG. 18

Fig. 18.—Showing the pattern of the distribution network within a AGC service area.

associated with it a power unit which can be adjusted to accept the voltage on the cable. This would contain a step-up transformer for supplying HT, and a step-down winding for LT.

EXTRA WINDING

An additional winding or tapping is sometimes incorporated for passing on from that unit to the subsequent cable an increase in line voltage for operating the next repeater, and so on, for it must be remembered that a certain amount of voltage is lost due to the resistance of the cable.

There is usually little difficulty in powering three repeaters in tandem on a common cable in this way, but if a greater number of repeaters is used, then it may be necessary to introduce auxiliary power at some remote point in the network. The total number of repeaters which can be so powered in one cable, one after the other, is governed by the power requirements and loading of the repeaters themselves and the resistance of the distribution cable.

It is, of course, necessary to employ a repeater and power unit which are specifically designed for line powering. An ordinary mains-operated repeater is unsuitable. Wideband repeaters, owing to their large number of valves and relatively high power loading, are in general unsuitable for line powering.

CHAPTER SEVEN

Line Powering and Equalisation

SUPPLYING power to a medium or large relay system can be quite a task, and an expensive one at that, if each repeater requires to be powered from the mains supply individually. The mains installation costs on 50 to 100 repeaters might well fall in the range of £500 to £1,000, depending upon the actual siting of each repeater in relation to a convenient mains feed. Then there is the payment for electricity at each point. Where possible, it is as well to avoid metering and operate each point on an annual basis. Payment is usually rated at 100W per annum at a figure scaled to local charges. As an example, each 100W

mains point may be costed at £4 10s. per annum and any fractional part of 100W at a minimum of £3 per annum.

A repeater loading is usually less than 100W which, in the example given above, means that the minimum electricity charge per point per annum is £3. With a system of 100 repeaters the electricity cost alone is £300 per annum. It must be borne in mind, of course, that once a relay system is switched on, the only time it is ever switched off is when maintenance so demands. Time switches are deprecated, not only from the possibility of the time switches themselves causing trouble, but because a valve has a far longer life if it is left operating all the time. Remember, in a large relay there may be as many as 500 valves in the overall system!

CONSTANT VOLTAGE

Again, in order to reduce the valve fault-rate a constant voltage at each repeater is highly desirable. In most areas these days the mains voltage tends to deviate frequently from its nominal value over the course of 24 hours. Thus, there is the additional cost of constant-voltage transformers at each repeater when individual powering is adopted. However, it should be noted that the power units in certain repeaters are voltage stabilised; but, of course, this adds to the cost of each repeater, though this method is possibly more economical than constant-voltage transformers of the saturated-core type.

A constant voltage is also desirable to alleviate overloading at repeaters. Consider, for instance, a repeater carrying four channels in Band 1. The maximum signal output voltage per channel available before non-linearity causes cross-modulation (e.g., cross-talk between channels) is very much dependent on the heater and HT voltages. Thus, if a repeater is set-up towards optimum output, a small fall in the mains voltage might well cause the repeater to overload, giving the undesirable effects of cross-modulation.

Line powering has several advantages over individual powering. It allows at least eight repeaters to be powered from a common mains supply point. On the same basis as that mentioned earlier, a system using 50 to 100 repeaters could be installed (mains-wise) for £60 to £120, as against £500 to £1,000, while a system of 100 repeaters could be powered for a year for a cost of £144, as against £300 for individual powering. This in itself is a worthwhile saving, but in addition, there is the saving in constant-voltage transformers or voltage stabilised power units, for in a system of 100 repeaters there may be only 112 mains points requiring voltage stabilisation. Moreover, the repeater power units can be less complex and thus less costly.

Another large advantage is that there is no need to plan for power, as power is available in the signal-carrying cable wherever it may be required. With individual powering, there is always the temptation to site a repeater for easy access to the mains supply, at the expense of the signal conditions. In this way a repeater could be sited too close to the previous one, making for a smaller number of subscribers per

repeater, or too far removed from the previous one, thereby upsetting the overall signal balance in the network.

In many cases, where tracts of trunk cable are to be taken across country or from one distribution zone to another, the only economical way of powering inter-trunk repeaters is over the cable at low voltage. The cost of running a mains link over a mile or so just to power a 60W repeater could be prohibitive.

Line power applied to the signal-carrying cables is at low potential, about 50 to 65V, 65V rms being the maximum that the Post Office permits to be applied to such cables. This power can be injected into the cable network at almost any point, provided the repeaters are designed to accept the power at both the input and output signal sockets; but it is convenient, especially in large systems, to apply the line power at key distribution points, such as AGC Systems. At distribution points of this nature a single mains power point and low-voltage transformer can inject line power into several outgoing trunk cables (see Fig. 19).

Line power is isolated from the signal, and the signal from the line power, by injecting the line power via a low-pass filter (see Fig. 8). Power from the cable is likewise extracted at each repeater point so as to operate a low voltage power unit. The general idea is depicted in Fig. 19, which shows the 1-1 constant-voltage transformer connected to the local mains supply, the output feeding the AGC or distribution equipment and also the line power transformer. This transformer has a primary to suit the output of the constant voltage transformer, and a secondary giving 65V rms. The 65-volt output is applied to each of the outgoing trunk cables, via power filter chokes L, while the signal to each of the trunks is applied via capacitors C. Capacitor C1 is a filter for the line power.

Figure 20 reveals how the line power is extracted from the signal cable at repeater points and how it is conveyed to the power-unit transformer T1. Both signal and line power are present at the input and/or output signal socket of the repeater. If the line power is applied in the direction of the signal, it is accepted at the repeater signal input socket, while if it is applied in the opposite direction to the signal, the line power is accepted at the signal output socket. As it is convenient to be able to line-power subsequent repeaters in the network, there is invariably an arrangement to allow the line power to pass through the repeater (from input to output or from output to input) and at the same time to give a boost to the voltage to counteract inevitable voltage drop in the previous cables.

In Figure 20 it is assumed that the line power is applied in the direction of the signal. The input signal socket of the repeater thus receives both components. Capacitor C1 blocks the line power from the signal input circuits, while inductor L1 has a high impedance to the RF but allows the line power unrestricted passage to a suitable tapping on the transformer T1. The tapping selected is that which coincides with the line voltage actually present at that repeater input.

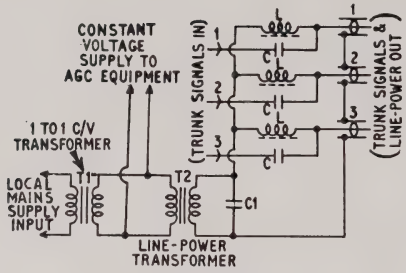


FIG. 19

Fig. 19.—Showing how line power, as well as signal, is applied to each outgoing trunk cable, via low-pass filters L and C. A 1/1 constant-voltage transformer supplies both the line power transformer and the AGC or distribution equipment.

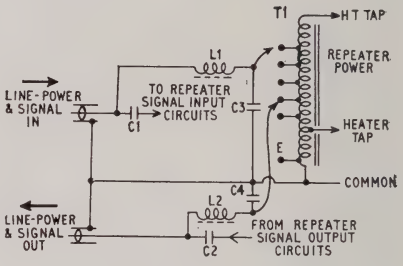


FIG. 20

Fig. 20.—Line power is applied to the repeater power unit either at the input or output repeater signal socket, via low-pass filter L1/C3 or L2/C4. Line power is also stepped up through auto-transformer, T1 to power subsequent repeaters in the cable network.

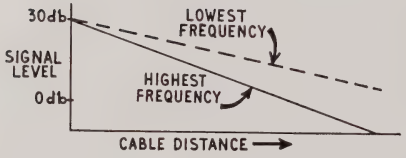


FIG. 21

Fig 21.—This diagram shows how the higher frequency signals are attentuated to a greater extent than the lower frequency signals over a cable network.

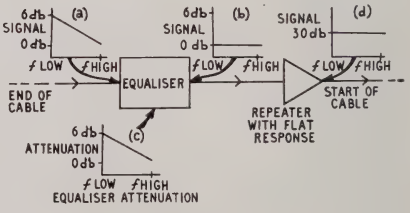


FIG 22

Fig. 22.—This diagram shows how the introduction of an equaliser ensures that all the signals are of equal level at the input to a repeater.

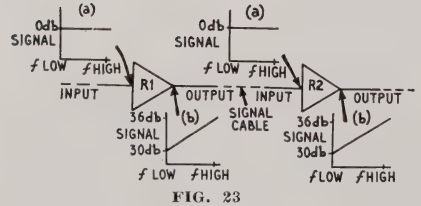


FIG. 23

Fig. 23.—A method of equalisation in which the response of each repeater is sloped.

ENERGISED

The transformer is thus energised, and suitable additional tappings provide the correct voltage for the heaters of the repeater valves (these often being series-connected) and HT voltage for applying to the rectifier.

If it is not required to line-power further repeaters the signal output socket on the repeater is isolated from line power by connecting the flying lead at the junction of L2/C4 to an earth socket. However, if subsequent powering is required, the flying lead is connected to a tapping on the transformer which provides 65V rms at the signal output socket. Again, L2 allows free passage of the line power to the output socket while leaving the RF unaffected, and C2 isolates the line power from the signal output circuits of the repeater without attenuating the RF.

From this description in conjunction with Fig. 20, it will be appreciated that line power can be applied in either direction through the repeater without in any way affecting the operation, it simply being a matter of selecting the correct voltage tapping on the transformer. Capacitors C3 and C4 are, again, line power filters.

LIMITS OF LINE POWERING

There are several factors, governing the extent to which line-powering can be extended over a common power network. The voltage drop in the signal carrying cables is a large factor which, of course, depends on the DC resistance of the cables themselves and the amount of current in them. The total "through current" that the first power-unit transformer is able to handle without overloading is another factor. With a repeater system taking about 35mA at 65V, up to four repeaters can be line-powered one after the other from a single power source. It should be understood, of course, that the same power source may also feed several additional common power networks.

A repeater system providing through amplification of the whole of Bands 1 and 2 rarely takes more than 35mA at 65V and this method of line powering is easily catered for. With large repeaters, line powering is often out of the question. In this case mains cables are sometimes carried alongside the signal carrying cables to avoid having to establish a mains point for each repeater on route.

EQUALISATION

If the signal levels over the entire range of frequencies embraced by the system are equal at the output of a repeater or distribution point, at the end of the cable this will no longer be the case. This is because the cable attenuates the higher frequency signals to a greater extent than the lower, as shown by the diagram in Fig. 21.

Over a length of cable of approximately 500 yards the difference in the levels at the end of the cable from one end of Band 1 to the other may be as high as 6dB, even though equal signal levels are applied at the start. The difference will be even greater between the bottom of Band 1 and the top of Band 3.

If no correction is made for this frequency-versus-attenuation factor, not only do the higher frequency signals disappear below "noise" in an extended system, but the lower frequency signals are of great relative strength and tend to overload the intermediate repeaters. This results in severe cross modulation, becoming progressively worse towards the end of the system, as the signals fall more and more out of balance.

In order to avoid cross modulation troubles it is essentail that all signals applied to the input of any repeater in the system are of equal level. This applies to both vision and sound signals, though with sound the level is usually kept 6dB below the vision level. Thus, after the highest frequency signal has been attenuated by the cable to a level requiring further amplification, a form of equalisation must be interposed between the cable and the input of the repeater. This provides a graduated attenuation from the highest to the lowest frequency signals, with a frequency-versus-attenuation factor opposite to that of the cable itself.

The general set-up is shown in Fig. 22. The out-of-balance signals at the end of the cable run are given at curve (a) between the lowest and the highest frequencies. The balanced signals at the output of the equaliser are given at curve (b), due to the equaliser response (c), and the amplified signals are given at curve (d). It will be noted that the signals at the output of the repeater are also balanced, which implies that the repeater must have a flat response over the band of frequencies it is amplifying.

An alternative method of equalisation is shown in Fig. 23. Here the response of each repeater is such that the higher frequency signals provide an output in the region of 6dB above the lower frequency signals. Thus, the gain of the repeater (over Band 1) may be 30dB at 40 mc/s and 36dB at 70 mc/s. At the end of the cable run the levels wll have balanced and are suitable for direct application to the next repeater, as shown by curves (a). The output of each repeater will then be as shown by curves (b).

TWO ADVANTAGES

This method of equalisation has much to commend it. Two advantages are that signal is not thrown away unnecessarily in equalisers, and the response of the repeaters can be set for optimum bandwidth/gain over the entire operating frequency range. A control can also be made available for adjusting the response slope over 1 or 2dB to allow it to suit any normal length of cable run. It is essential, however, that such repeaters are supplied with an accurate response curve so that the slope is known to the relay operator.

In some systems use is made of both methods of equalisation. Equaliser units are usually employed on trunk cables exclusively, while sloped response repeaters are used on subscriber spur cables together, if necessary, with equaliser units.

CHAPTER EIGHT

Distribution Network

THE distribution network of a coaxial relay system comprises the coaxial cable through which the required programme signals are propagated, the resistive, capacitive, inductive or transformer splitter units and spur take-off pads which allow expansion of the cable runs, and the repeater amplifiers which serve to balance the network losses against factors of gain.

The aim in design is for an overall distribution network which has neither loss nor gain; one, in other words, which is "loss-free" over the range of operating frequencies between the signal launching point and the remote terminations of the network. When this condition is achieved, a signal of x mV introduced at the input will result in a signal of x mV at the remote terminations. It will be recalled that the process of equalisation ensures that the network remains balanced in this way over the entire range of signal frequencies used—see Fig. 24.

The signal levels launched upon the loss-free network depend on several factors, such as the level of signal on all channels the repeaters can provide without overload, the radiation factor of the coaxial cable and the ratio of attenuation between the network cable and subscribers' take-off pads.

TRUNKS AND SPURS

These factors, however, need not be taken into account during the initial planning of a system, which can be likened to the planning of a network of roads upon which the traffic (signals) will be launched later. Nevertheless, the roads must be designed to suit the traffic they are eventually to carry; and like ordinary roads, "relay roads" are made up of trunks and spurs. The diagram in Fig. 25 gives the general idea. This shows a part of a trunk network and spur cables connected to it. Spurs of this kind would also be connected from other trunk sections in a similar manner. The initial planning boils down to an exercise in logic leading to a network having neither loss nor gain between the signal input point and any termination.

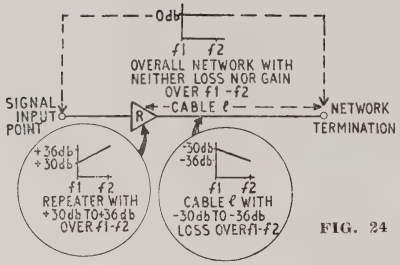


FIG. 24

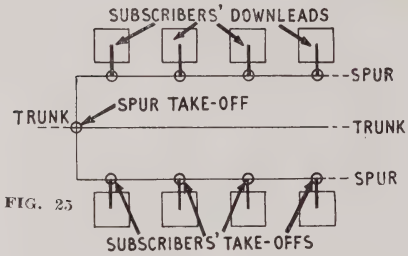


FIG. 25

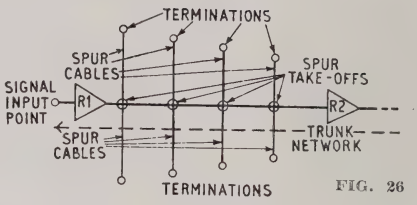


FIG. 26

Fig. 24.—A simple network configuration which has neither loss nor gain.

Fig. 25.—A distribution network comprising a trunk and spurs. The spurs are fed from the trunk via take-offs and subscribers are fed from spurs also, via similar take-offs.

Fig. 26.—In some cases it may be necessary for a spur cable to run parallel with a trunk cable.

The problem is somewhat more complicated than that revealed in Fig. 24 since factors other than just a virgin (unloaded) cable and a repeater are involved. To start with, the network can never be the ideal as it has to follow the pattern of the various properties on which the cable has to be carried. Further, the trunk cable in Fig. 25 is loaded by spur cables via spur take-off pads. The pads are necessary in order to extract the required amount of signal from the trunk cable. They, therefore, load the trunk to some degree depending on just how much signal is required for the spur; the greater the signal taken from the trunk the greater the loading. Loading of any cable is the same as the attenuation of the cable being increased. Clearly, then, the total network loss is made up in part by the cable attenuation and in part by the loading effect of the take-off pads.

Before continuing, however, the purpose of the two types of network should be made clear. The trunk serves primarily to carry the signals from one area to another and to feed the spurs, while the signals in the spur cables are extracted, again by take-off pads, to feed the receivers connected to the system through subscribers' downleads. Trunk cables are not usually connected direct to subscribers' downleads, which means that in some cases a spur cable may have to run parallel with a trunk cable, as shown in Fig. 26.

SPLITTING PROCESS

In order to facilitate correct expansion of a network it may be necessary to split a main trunk or spur cable two or three times as shown in Fig. 27 (a) and (b). As would be expected, this splitting process also adds to the losses of the network. In spite of the extra losses

incurred, however, splitting allows a larger extent of cable to be energised with signal than would be possible with a single cable run.

If the take-off loading losses are ignored and it is supposed that the cable has an attenuation of 5dB per 100 yards and the repeater a gain of 30dB at a nominal frequency, then the cable in the simple network of Fig. 27 (c) could be extended 600 yeards in terms of the loss balancing the gain of the repeater. Now, a two-way splitter of the resistive kind has a loss of 6dB between the input and each of the outputs. Thus, each subsidiary cable in Fig. 27 (a) could be extended almost 500 yards, giving a total of 1,000 yards of cable energised. This could be increased slightly by the use of a coaxial transformer splitter which has a loss of only approximately 3dB between the input and each of the outputs.

Even greater economy is possible by the three-way split of Fig. 27 (b), as will be seen. A three-way resistive split has a loss of approximately 9dB between the input and each of the outputs, which means that three 400-yard lengths of cable can be energised, giving a total of 1,200 yeards. This process can be continued, of course, but after a certain number of splits the splitting attenuation is too great to allow a reasonable run of cable, bearing in mind that the signal in the cables has to be used and that this means loading losses. The splitting attenuation can be calculated from the expression $dB = 20 \log_{10} n$, where n is the number of splits. The same information can be obtained from an ordinary table of dB values, in which n is the voltage ratio. Thus, a ten-way splitter of the resistive variety has a splitting attenuation of 20dB.

CAN BE EXTENDED

After the network losses equal the gain of the associated repeater, the network can be extended by the addition of a further repeater. Many tandem-connected repeaters are, of course, necessary to extend a trunk cable from one end of a town to the other, and this may well apply also on subsidiary trunks which are fed from a splitter—see Fig 28.

In some cases it may also be necessary to extend a spur cable by way of a repeater, but this method is not generally desirable because the resulting mismatch caused by the connection of subscribers' take-offs tends to introduce standing waves which may be amplified by the spur repeaters and the effects carried on to the remote ends of the network. These effects will be described in detail later. One or two spur repeaters are, however, quite in order.

The connection of a spur cable to a trunk cable is accomplished by means of a "junction box" containing a resistive pad network or coaxial or other type of transformer. The main line signals are passed through the network or transformer and the required quantity of radio-frequency energy is transferred to the spur outlets or outlets, as there may be several spur cables fed from a single box.

When such a spur box, or "teeing unit," as it is sometimes called, is connected to a main network the through cable loss is increased be-

cause of the energy which is extracted and the impedance discontinuity due to the cable having to be broken and reconnected in the box. These factors also give rise to the signal being reflected back down the line, producing mismatch and standing wave conditions.

LOADING LOSS

Moreover, the "through" attenuation of the junction is influenced by the amount of signal drawn from the main cable, the more signal drawn the greater the through attenuation. It has already been shown that a two-way resistive splitter has a through loss in each direction of —6dB. It follows, therefore, that with the attenuation values between the main line and the spur greater than —6dB the through attenuation will be less than —6dB. For example, with a 10dB tee atttenuation figure, the through loss is about —1.3dB, while with a 24dB tee attenuation figure, the through loss is a little under —0.5dB. These figures relate to resistive networks only, and the through loss is often referred to as "loading loss." Apart from the tee or "take-off" value to the spur, the total loading loss value is also influenced by the design of the associated junction box, the better the design the lower the loss.

The same reasoning applies, of course, to the soldering or clamping of the various cables in the box, for the advantages of a well designed box may well be lost due to poor workmanship or, indeed, to too zealous clamping of the cable beneath a cable clip.

The most popular method of extracting signal from a main cable is by placing a relatively high value resistor (hold-off resistor) in series with the spur cable and a low value resistor in parallel, as shown in Fig. 29. This same method is also often used in extracting a signal from a spur cable to feed a subscriber's downlead. In some cases, however, the parallel resistor is eliminated, leaving just the hold-off resistor Rh. The tee attenuation value is then governed by the value of Rh used, according to the expression $dB = 20 \log_{10} \frac{Z + Rh}{Z}$ where Z is the impedance of the spur cable at its point of connection to the hold-off resistor.

REASONABLE MATCH

If the parallel resistor is not used, on small spur cable runs or subscribers' down leads, standing waves due to mis-match may cause trouble and give rise to unpredictable signal levels and radiation problems (or interference pick-up on the cable, which is the reciprocal of radiation). The parallel resistor is then used, and its value should equal the characteristic impedance of the spur cable or downlead. A resistor of 100 ohms usually provides a reasonable match, since this value, in conjunction with Rh and the parallel impedance of the main cable, looks very close to 75 ohms, which is the nominal characteristic impedance of most coaxial relay cables. When a parallel resistor is used, the

tee attenuation value is increased by approximately 6dB over that given by the foregoing expression.

The loading attenuation at the main cable due to the effect of the hold-off resistor in dB is approximately equal to $20 \log_{10} \left(\frac{Z+Rh+\frac{Zm}{2}}{Z+Rh} \right)$ where Zm is the impedance of the main cable at the point of connection to the hold-off resistor.

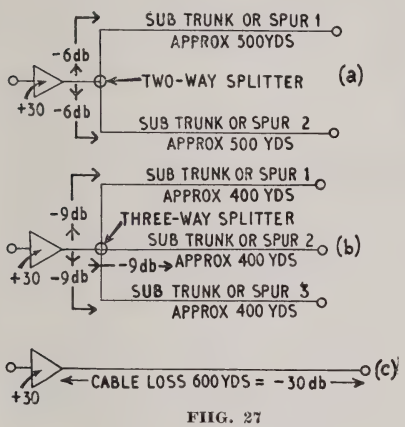


FIG. 27

FIG. 28

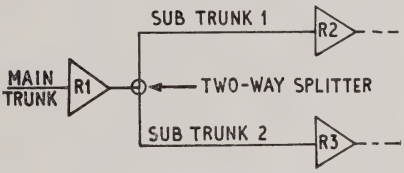


Fig. 27.—By the use of splitters the main trunk or spur may be split two or more ways. This results in greater lengths of cable being energised from a single repeater.

Fig. 28.—It is possible to extend a subsidiary trunk by way of repeaters, but extensive extension of spur cables by this means is deprecated.

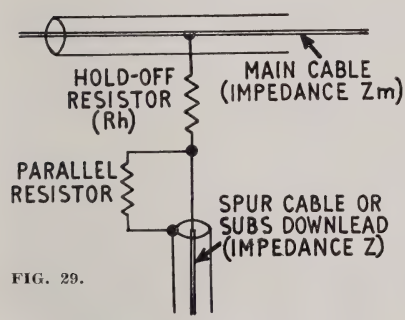


FIG. 29.

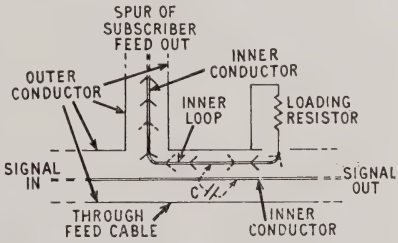


FIG. 30

Fig. 29.—The resistive method of extracting signal from a trunk or spur cable to feed a spur or subscriber's downlead.

Fig. 30.—The basic principle of the directional coupler.

Spur, junction and outlet boxes, in which the network in Fig. 29 is housed, have of recent years undergone severe re-design to ensure that the main cable is held as close as possible to its characteristic impedance in spite of having to be cut and joined internally. The Belling and Lee subscribers' outlet box is typical in this respect. The base and the lid of the box fit snugly around the dielectric of the co-

axial cable, the outer conductor being dressed back, to form a new outer conductor. The spur cable enters and leaves the bottom of the box to avoid the ingress of moisture and, in turning through 180 degrees, describes a semi-circle of large radius. The outer conductors are clamped carefully at the inlet and outlet to avoid distortion of the cable concentricity.

There are a variety of ways of achieving a correct impedance match through the box and to compensate for the small capacitance which is reflected on to the main cable as the result of connecting the hold-off resistor. In the Belling and Lee box the distributed capacitance between the inner and outer conductors of the cable is reduced by four small cavities formed in the concentric casting of the box (which acts as the new outer conductor) near to the tap off point.

DIRECTIONAL COUPLER

The directional coupler is used extensively in wave-guide practice to couple a signal in one circuit to another circuit. The advantage of the directional coupler is that it responds only to a wave travelling in one direction in the transmission line or wave-guide. This principle has been adopted by EMI and is used in their community television systems for extracting signal from a trunk to feed a spur and from a spur to feed a subscriber.

The diagram in Fig. 30 reveals the basic features of the directional coupler. The through feed cable is introduced in the trunk or spur and the signal passes through this in the ordinary way. Also in the cable, within the coupler, is an inner loop comprising a separate inner conductor running parallel with the main inner conductor of the through cable. One end of this is terminated by a load resistor and the other end is connected to the inner conductor of the subscriber feed out.

The electric component of a wave travelling from "signal in" to "signal out" in the through cable will induce a charge in the inner loop via the distributed capacitance between the inner loop and the inner conductor, shown as C in the diagram, and produce currents which flow in both directions, as indicated by the broken-line arrows.

The magnetic component of the same wave in the through cable will also induce a current in the inner loop in the direction shown by the full-line arrows. The two waves flowing in the same direction in the inner loop will add while the two waves of opposite polarity will cancel each other. Thus, a signal is effectively transferred from the through cable to the spur or subscriber feed out.

Moreover, a spurious wave travelling in the opposite direction in the through cable will be eliminated in the feed out due to cancellation of the electric and magnetic components, since then the conditions would be reversed. The two components will add, however, in the direction of the load resistor, but as this matches the line the spurious wave will be absorbed.

Since signal energy is extracted from the main cable, the introduction of this type of take-off will also introduce extra attenuation, as with

the resistive type. Typical values are 1dB loading loss for 10dB tee attenuation and 0.6dB loading loss for 16dB tee attenuation.

Clearly, then, in designing a distribution network, factors other than the attenuation of the cable need to be taken into consideration. Nevertheless, it is desirable to equate a network in terms of zero loss, as has already been described, whilst having in mind the added attenuation which will be presented to the network as a whole by the introduction of splitters and spur and subscriber take-off pads.

CHAPTER NINE

Planning a Coaxial Network

WHEN planning permission has been obtained for erecting an aerial tower or mast and the initial wayleaves are cleared for routing the primary cable from the aerial station to the first distribution point, attention should be directed towards planning the cable routes within the town on a tentative basis. At this stage a definite working plan cannot be evolved, since the routes which will ultimately be taken by the cables will depend entirely on the wayleaves which have yet to be secured for private properties.

A 50in. Ordnance map of the whole area should be set up on a large wall of the planning room. This should embrace the aerial site and the primary cable run, and a line should be drawn from the first distribution point to the far end of the town to represent the trunk cable route. Several such lines will, of course, have to be drawn in a large town in which a number of trunk cables will be used.

Poor signal strength areas should also be indicated on the plan, as also should council properties for which wiring consent will have been obtained in the terms of the franchise.

Wayleave officers should be instructed to clear properties in proximity to the first distribution point as well as on the tentative trunk cable route, and then lead up to clear those properties in poor signal strength areas to allow the wiring to commence without delay. If possible, a route should be cleared to allow a trunk or subsidiary trunk cable to feed into or through the council property.

It helps to issue each wayleave officer with a map section of the area

in which he is operating showing the proposed cable routes. His aim should then be to secure an unbroken route on properties and across land, where necessary, to coincide as closely as possible with the route shown on the map section. He is not always able to follow the route exactly, of course, but aided by the map section he will be in a position to make diversions to allow the cable route to continue in spite of some wayleave objections.

In the majority of cases, the cable will be routed along properties just below the guttering and will cross detached and semi-detached houses, from one house to the next, overhead. It must be remembered that the spur cables are used to feed subscribers by cable taps or take-offs and that trunk cables are used only to feed spur cables. On long tracts of trunk cable it is possible to route this underground, provided that a means is made available to feed spur cables when required.

All wayleave permissions obtained should be marked by the wayleave officer on his map section, and these should be transferred to the master map at the end of each day. A green pencil outline around the properties cleared gives adequate indication of the wayleave position on the master map.

When there is sufficient continuity of "greens," a working plan can be produced ready for wiring. The idea, then, is to undertake detailed planning of a "loss-free" network in terms of attenuation and gain, in accordance with the basic principles given in Chapter 8. There are, however, one or two additional points which now have to be considered.

SPUR ATTENUATION

Whenever a signal is taken from one cable to another a loss occurs in the cable from which the signal is being taken. This applies, of course, to spur cables from which subscribers' signals are taken. The degree of such loss depends upon the amount of signal taken from the spur which, from the point of view of a subscriber, depends upon how much signal there is in the spur at the take-off point. If the take-off point is at the start of a spur where the signal is relatively high, then less signal will need to be taken off than at the end of the spur where the signal level is lower, relative, in both cases, to a constant level subscriber signal.

In other words, the tee or take-off attenuation from the spur to the subscriber's downlead will be greater at the start of the spur than at the end of the spur (see Fig. 31). Each tap or take-off of different value will thus give a different value of loading to the spur cable. The loading value may range from approximately 0.5dB with a 20dB tee loss to 0.1dB with a 35dB tee loss.

During the process of planning a system such loading losses may be averaged out over a spur cable, and a value of 0.25dB spur loading per tap is quite satisfactory. It will be realised, of course, that 100 per cent. spur loading will not exist at the start of a system, but as the subscribers build up over the months the spur loading will increase. It is always desirable, therefore, to plan for 100 per cent, participation.

The cable lengths are measured on the 50in. Ordnance map by

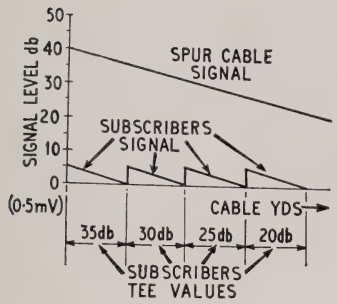


FIG. 31

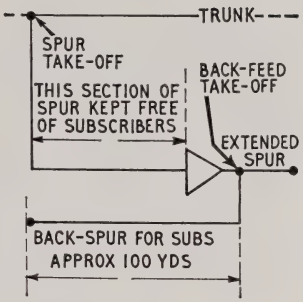


FIG. 32

Fig. 31.—Shows how the signal level in a spur cable falls along its length. Subscriber signal levels are also indicated as obtained from the subscriber tee values indicated. The tee atentuation of necessity decreases towards the end of the spur to maintain a relatively constant subscriber signal level. In order to maintain sufficient isolation between subscribers tee values should never be less than 20dB.

Fig. 32.—When an extended spur repeater is used then back feeding should be adopted in order to allow a 100-yard section of cable feeding into the repeater to be kept free from subscriber loading.

means of a measuring wheel. However, in practice the amount of cable distance actually involved is approximately 25 per cent. more than that measured. This is due to variation in cable height throughout a run. With terraced property the excess yardage may not be so great as this, but it could possibly be greater where the cable is routed along a street of detached houses, for example, of different design.

HANDLING EXCESS CABLE

It is essential that this excess cable is taken into account during planning. The best way of handling this is by assuming that the cable has an attenuation 25 per cent. (or whatever tolerance is decided on) greater than that given in the specification. For example, if the cable is known to have an attenuation of 4dB per 100 yards, then it would be assumed to have an attenuation of 5dB per 100 yards in terms of the distance measured on the map.

The frequency on which the cable attenuation is based must be related to the gain of the repeater at that particular frequency and whether or not equaliser units are to be used. If equalisation is by means of a sloping response on the repeater, then it does not matter what frequency is used provided it is within the frequency spectrum of the repeater, and the repeater gain and the cable loss are balanced at that frequency.

However, if an equaliser unit is used, then the cable attenuation and repeater gain at the high-frequency end of the spectrum must be used. This is because additional attentuation to the lower frequency signals is caused by the equaliser. Moreover, if the equaliser has an insertion loss at the low-frequency end, this must also be taken into account during the planning.

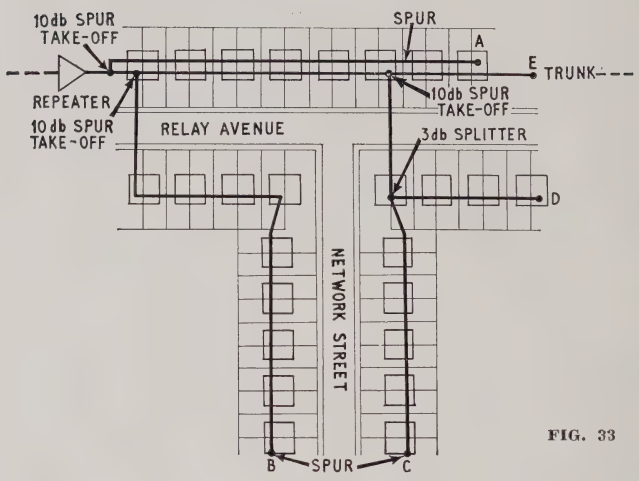


FIG. 33

Fig. 33.

Spur cable A	=	14db	Spur cable B	=	15db
Subs loading	=	4db	Subs loading	=	4.5db
Spur take-off	=	10db	Spur take-off	=	10db
TOTAL	=	28db	TOTAL	=	29.5db
Spur cable C	=	8db	Spur cable D	=	7.5db
Spur take-off	=	10db	Spur take-off	=	10db
Spur splitter	=	3db	Spur splitter	=	3db
Sub loading	=	2.5db	Subs loading	=	2db
Trunk to spur	=	6.5db	Trunk to spur	=	6.5db
TOTAL	=	30db	TOTAL	=	29db

Trunk Cabile to E	=	14db
Trunk loading	=	4.5db
TOTAL	=	18.5db

In Fig. 33 is shown a piece of planned network in detail. Here the repeater, which is assumed to have a sloping response, feeds the trunk cable E. Directly at the output of the repeater, this trunk feeds spurs A and B, and further along it feeds spurs C and D via a 3dB splitter.

The repeater is taken to have a gain of 30dB, which means that the total attenuation of any section of the network from the output of the repeater to the terminaion must not exceed 30dB. It can be less than this value, of course, but unless that particular section of network is later to be extended, it would always be desirable to use a higher attenuation spur take-off to secure a balance closer to 30dB. The reason for this is because a higher attenuation take-off will have less loading effect on the trunk cable, and thus enable that network to be extended over a greater cable distance before another repeater is required.

In the example diagram, the total trunk cable network attenuation is only 18.5dB, which means it can be extended over a greater distance, depending upon the spur loading and cable attenuation, before a further repeater is necessary. The next repeater would normally be introduced when the trunk cable network loss equals the gain of the repeater.

Exactly the same process is adopted from the output of that repeater, and so on.

This happens along the whole length of the trunk cable network until about a mile or so of cable has been used. At this point, instead of an ordinary repeater, an AGC system is introduced to correct all sound and vision signal levels and to counter the effect of variation of cable attenuation due to temperature change and alteration in gain of repeaters, etc. The AGC system also feeds additional trunk and subsidiary trunk cables as previously described.

As has already been intimated, it is not desirable to feed subscribers direct from a trunk cable on a large system. The reason for this is because the loading on the trunk would otherwise be affected each time a new subscriber is connected, and this would reflect through the whole of the subsequent system and give unpredictable variations in signal levels. This does not happen, of course, when subscribers are confined to spur cables, owing to the isolation between the spurs and the main trunk. A local variation over a few decibels in a spur due to this effect can be tolerated and kept under control.

It is sometimes necessary to extend a spur cable through a repeater as shown in Fig. 32. With this kind of network it is good policy to keep about a hundred yards of cable feeding into the spur repeater free from subscriber loading. This can be done, as shown in Fig. 32, by feeding the subscribers over that distance from a back spur fed from the output of the repeater. Some repeaters are, in fact, manufactured with a back feed output which is approximately 15dB down on the main output.

Back feeding is necessary to avoid standing waves occurring at the input of a repeater where their presence could affect the matching and cause continuation of mismatching effects in subsequent network. Some degree of mismatch is bound to occur due to the connection of subscribers taps, but by maintaining the cable free from loading over 100 yards the mismatch is considerably buffered from the point of view of the repeater input.

CHAPTER TEN

Signal Levels

SIGNAL level on a carrier at any point in a coaxial relay system is best considered in terms of decibels above or below an established reference level. The reference level, which corresponds to 0dB, is usually either 1mV or 0.5mV. The latter value is often favoured, for this is the signal level that relay engineers endeavour to secure on each vision carrier at subscribers' outlets.

Using this reference, a reading of, say, +6dB indicates a signal level of 1mV and a reading of –6dB indicates a level of 250μV (6dB being, of course, a 2-to-1 voltage ratio). In future text, 0dB signal level will be taken to correspond to 0.5mV.

Considering the signal levels in an equalised basic network configuration, as shown in Fig. 34, one can readily understand that a signal of XmV applied to the input repeater R1 will give rise to a signal of XmV at the input of repeater R2 and also at the termination of the spur cable.

It is accepted, of course, that the frequency of the applied signal is within the pass-band of the repeater and that the gain of the repeater at that particular frequency is equal to the loss of the network at the same frequency.

INTERMODULATION

The level of signal that can be applied to the input of a repeater is governed by the output signal which it is able to provide without intermodulation, and this, of course, involves the gain of the repeater as well.

For example, if a repeater is rated to provide, say, 150mV (which is 50dB up on 0.5mV) output on each carrier with an adequate intermodulation or cross modulation margin, and the gain is set to 30dB, then the maximum signal per carrier that can be applied is 20dB. This is simply the gain of the repeater plus the signal input in decibels, equalling 50dB.

This little sum illustrates why it is desirable always to work in decibels.

Whenever a signal level is given in voltage as in the specification of a repeater or piece of network equipment, it should immediately be converted to decibels, scaled to the 0dB established by the engineer. After a while this becomes an automatic mental operation.

It should be noted that the maximum signal output that a repeater is capable of supplying depends also on the number of carriers it will be handling. A far greater output within a given cross modulation margin is possible on only two or four carriers than if, say, eight carriers, corresponding to four television programmes, are carried on the system.

RADIATION

With any coaxial network there is always a loss of signal due to radiation from the cable. The amount of this radiation depends on the radiation factor of the cable and the level of the signal in the cable.

Radiation factor is sometimes defined as the ratio of the signal in the cable to that picked up on a tuned dipole 10ft. from the cable, stated in decibels. With the various new types of coaxial relay cable now available the radiation factor is remarkably small; even so, a high signal level may result in the leakage signal being sufficient to cause interference to viewers obtaining their signals through ordinary aerials.

As a general rule, the radiated signal picked up by a viewer's aerial should never exceed –46dB of the signal picked up direct from the transmitter. A smaller signal-to-interference ratio will produce pattern interference on a set working direct from an aerial.

If equalisation is accomplished by a rising repeater response, then the level of all carriers should be substantially equal at the input of each repeater, though the sound carriers may be of slightly lower level than the associated vision carriers. At the output of the repeater the signal levels will rise progressively from the lowest channel to the highest channel, as indicated in Fig. 35.

If the repeater has a flat response and an equaliser is used at its input (Fig. 36), the carrier signals will have a rising level from the highest to the lowest channel at the input of the equaliser, but the levels at the output of the equaliser will be equal, and this also applies at the output of the repeater, as the diagram shows.

An equaliser is not necessarily inserted close to the repeater input but may be fitted at some intermediate point of the cable network to equalise for a certain length of cable. Teleng equalisers are, in fact, graded in terms of slope over three lengths of certain type cable, e.g., 600, 800 and 1,000 feet.

This makes the selection of equalisers relatively simple; if an equaliser is inserted at some intermediate cable point, variation between the level of the highest frequency carrier and the lowest frequency carrier at any point in the network is reduced.

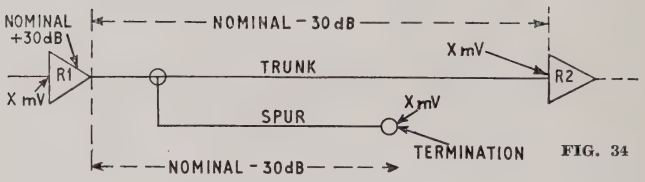


Fig. 34.—A signal of XmV applied to the input of R1 on this equated network will also appear at the input of R2 and at the spur termination.

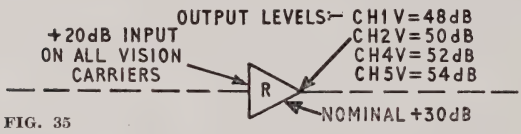
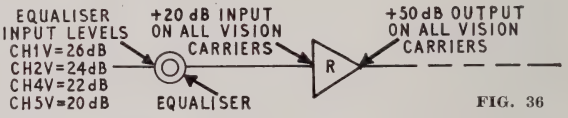


Fig. 35.—The input and output signal levels associated with a repeater with a rising response for equalisation.

Fig. 36.—The input and output signal levels associated with a repeater with a flat response and equaliser.



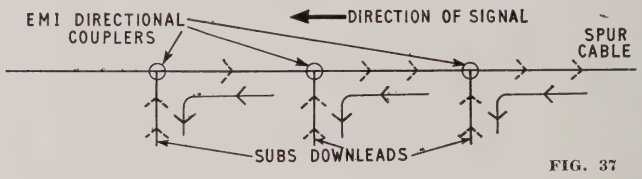


Fig. 37.—A signal in the direction of the full-line arrows in the spur cable will couple a signal to the subscribers' downleads, as shown, but spurious signals injected into the downleads will couple a smaller signal into the spur in the opposite direction (broken-line arrows), and will not gain admittance to the other downleads. This is now the high subscriber isolation results from the use of EMI direction couplers.

If the signal levels at the output of the repeater in Fig. 35 are applied to the network in Fig. 34, the signal levels at the termination of the spur and at the input of R2 will be substantially the same as those levels applied to the input of repeater R1. These will cater for the signal input requirements of repeater R2, and will also give a range of vision carriers at a level of 20dB at the spur termination.

However, if equalisers are used in front of repeaters R1 and R2 in Fig. 34 and the repeaters have flat repsonses, as Fig. 36, the signal levels at the spur termination may range from 26dB at Channel 1 to 20dB at Channel 5, depending on the slope of the cable used. Signal levels in a similar pattern would also appear at the input of the equaliser at R2.

Assuming a 6dB slope, subscribers connected towards the termination of a spur on a system with sloped or equalised repeaters would obtain substantially equal signal levels on all carriers, while those subscribers connected at the beginning of a spur would obtain signals rising in level

from Channel 1 to Channel 5, with a maximum difference between the two extreme channels not exceeding 6dB.

With a system using equalisers, subscribers connected at the beginning of a spur would obtain substantially equal signal levels on all carriers, while those subscribers connected towards the termination of a spur would obtain signals rising in level from Channel 5 to Channel 1, again, with a maximum difference between the two extreme channels not exceeding 6dB.

From this aspect, there is little to choose between the two methods, but with intermediate equalisers there is a possibility of decreasing the signal level difference between the two extremes of Band 1. With a flat repeater and equalisers there is less possibility of intermodulation occurring as the result of one carrier being of excess level and causing overloading of the repeater. With a sloped repeater the signal level on the highest frequency channel should never fall below the level of the lowest frequency channel. This is sometimes considered as a desirable feature, since some receivers become progressively less sensitive at the channel is raised. When this is true, then the receivers themselves tend to equalise for the difference in subscriber signal levels.

GENERAL STIPULATION

It is a general stipulation with relay systems that the signal level of each vision carrier shall not differ between subscribers by more than ±3dB from a minimum of 0.5mV and a maximum of 1mV, and that the difference between the levels of all the vision carriers at each subscriber should never exceed 6dB. The same tolerance is also accepted on the sound signals, but it is permissible for the sound carriers to be as much as 6dB down on the associated vision carriers.

This lower sound level may, in fact, be desirable for two reasons. One, it reduces the total signal output voltage required from a repeater and thus alleviates overloading and intermodulation effects when a system is carrying multiple signals. Two, it ensures that the sound rejector circuits of connected sets are not called upon to handle vision and sound signals falling outside the normal ratio of levels.

For instance, if a sound signal of equal or greater level than the vision signal is applied to some commercial receivers certain shortcomings in their rejector circuitry are revealed as persistent sound-on-vision interference, which is difficult, if not impossible to eliminate by adjustment to the fine tuner or by realignment of the rejector circuits.

For each subscriber 0.5mV or 0dB is the aim. This is relatively easy to provide by selecting the required take-off value once the signal level in the spur cable is known. If the spur signal level is calculated to be, say, 20dB (preferably at the highest frequency vision carrier), then OdB will be available at the subscriber's receiver if a 20dB subscriber's take-off is introduced at that point.

There will, of course, be a small loss in the subscriber's downlead, but this is usually ignored unless the downlead exceeds about 50 feet, in

which case a take-off giving a slightly greater subscriber's signal across its terminals would be used.

SUBSCRIBER ISOLATION

Isolation between adjacent subscribers is equal to the sum of the take-off values used in the case of resistive take-offs. Thus, if two neighbouring subscribers each have a –20dB take-off, the isolation between receivers is 40dB, plus the small loss between the two take-offs in the cable. It is, indeed, also a stipulation of the Post Office that the isolation between the subscriber's downlead and the main shall not be less than 18dB.

This can be satisfied provided the signal level at the end of the spur does not fall too far below 20dB. If the output of a repeater does not permit this, the spur should not be equated to 30dB, but to a smaller value which will ensure sufficient signal towards the spur termination.

With the EMI type of directional coupler the attenuation between the spur cable and a subscriber's downlead may be as low as –10dB but the reverse attenuation into the spur is far greater. Moreover, a spurious signal injected into the spur from an interfering receiver would occur in the opposite direction to that of the required signal, and would thus be rejected by the neighbouring couplers, as illustrated in Fig. 37. In this way a high isolation between subscribers is accomplished in spite of a relatively low spur to downlead attenuation.

Another general requirement is that the subscriber's receiver must be isolated from both the inner and outer conductors of the downlead. With the resistive type of take-off, isolation is achieved by small 0.001mF capacitors of suitable rating connected in series with the two downlead conductors either at the take-off box or at the subscriber's outlet box. Isolation may also be via a transformer, and this is, in effect, the case with the EMI type couplers.

CHAPTER ELEVEN

Noise, Picture Definition and Inter-modulation

HAVING launched the distribution signals on a balanced coaxial network, various factors will probably require attention before the signals can safely be sold to subscribers. After the signals have first been applied

to any section of a new network it is always a good policy to establish several test subscribers at key points in the section for about three weeks before making the signals generally available to the viewing public.

This practice allows sufficient time for the equipment engineer to make final adjustments to signal levels, network balance and so on. It also gives the equipment a reasonable length of time to settle down, for it has been proved that if a fault is likely to occur in a piece of relay equipment it invariably occurs within the first two or three weeks of operation.

On no account should a signal which falls below the quality of off-air signals in the area be made available for sale. The first impression is most important in relay; the signals must be good to start with and should always be maintained at the same high level quality if the relay company is to prosper.

SHORT CIRCUITS MAY BE FOUND

When a new section of network is energised, various faults will be apparent. If semi-skilled staff or operators not highly skilled with regard to coaxial cable undertook the erection of the network, which is the usual practice, the odd short-circuit will possibly be found at a junction box or teeing unit. If soldering has been necessary at coaxial terminations and junctions, the occasional case of a short-circuit between the inner conductor and outer braiding, due to excessive or prolonged heat causing the dielectric to melt, will also be discovered.

In spite of the wiremen having been instructed in the erection of coaxial cable, a very sharp bend or compression of the cable under the securing clip may give trouble. With certain copper-tape cables, a sharp bend may cause the tape to fracture, and although this may not be immediately apparent, it is likely to aggravate radiation owing to distortion of the able concentricity leading to a mismatch.

Before the cable section is energised, particularly if the repeaters are to be line-powered over the co-axial, it is desirable to make resistance and, if necessary, insulation tests on the network. Owing to the low loop resistance of coaxial cables, the "Megger" Circuit Testing Ohmmeter, which has two ranges—30ohms and 300ohms full scale, is extremely useful. The loop resistance of the cable sections can be measured, and the instrument has been found accurate enough to provide an indication of cable lengths in terms of loop resistance. A short can also be located within a few yards along the cable.

With a new system the station equipment would possibly have been operating for several weeks before the signals at its output are applied to the distribution network. Where possible, this should always be done. Not only does this practice allow the equipment engineer to become conversant with the basic operation of the station plant, but it also allows time for a soak test under normal working conditions. During this period every endeavour should be made to obtain the best possible picture and sound quality, which will almost certainly call for careful adjustment to the associated equipment and inter-connections.

The picture and sound quality as monitored at the output of the station equipment should be as good as the quality of the signals from the aerials. The strength of the signals at the output will, of course, be very much greater than the signals at the aerials, and while the aerial signals may only average, say, 0.5mV, the signals may be as high as 2V RMS at the output termination.

WILL BE AMPLIFIED

Nevertheless, it should be fully understood that any coaxial relay system can only repeat and amplify in terms of quality the signals fed in from the aerials. If there is noise on the signal, then this will be amplified by exactly the same amount as the signal itself. A relay system cannot enhance the quality, but only repeat what is applied to it. A slight, progressive deterioration in signal quality is inevitable from the start to the finish of a network. This is because the signal circuit comprises a large number of valves and tuned-circuits, and also because all relay networks are somewhat of a compromise in design.

For these reasons it is highly desirable to convey the signal across the whole of the distribution area through as few repeaters as possible. The trunk cable method of distribution, as described in chapter 5, takes care of this, and if very low-loss cable is employed, loaded as lightly as possible by spur cables or subsidiary trunk cables (and not subscribers' downleads) then only one or two repeaters will be required every mile. Local distribution will, of course, require feed repeaters, but there will rarely be more than two or three in tandem.

Generally speaking, picture noise will occur only at the masthead amplifier. If the network is properly planned, the signal level at the input of each repeater will always be far in excess of the equivalent noise figure of the repeater. Typical figures are signal 5mV, equivalent noise figure 10 microvolts, which means that the noise is some 55dB down on the signal.

On the other hand, the aerial signal may only be, say, 50 microvolts (on a Band 3 channel) and the noise figure of the masthead amplifier may be 5 microvolts. In this case the noise will be only 20dB down on the signal and will almost certainly show up as picture grain, which will run through the whole system.

It is most important, therefore, to secure the best possible signal-to-noise ratio at the station. In extreme cases, where the aerial signal is very low (and several systems known by the author operate successfully with a Band 3 signal of 20 microvolts!), a very low-noise masthead amplifier must be used. Also as much signal as possible must be extracted from the aerial, even if this necessitates stacking two or more aerial arrays.

If the masthead is fed with a relatively low power voltage from the station, the tapping on the supply transformer must be very carefully adjusted to ensure that the masthead is always receiving the correct power voltage. A drop in voltage of 10 per cent. will substantially increase the noise figure of the masthead and impair the overall signal-

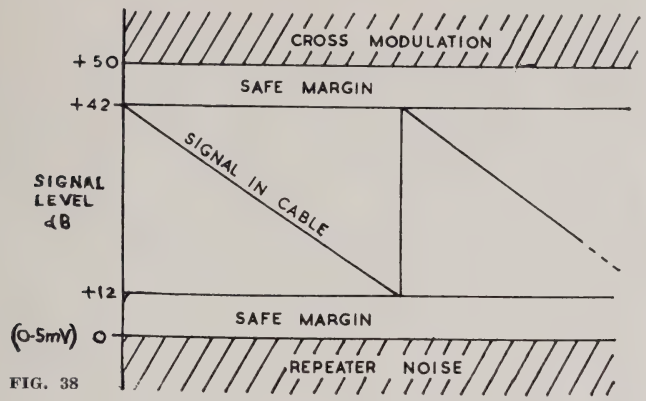


Fig. 38.—Showing the cross-modulation and noise working limits of a typical Band 1 repeater. The decibel values refer to one vision channel only when the repeater is handling three vision carriers and three sound carriers. 0dB is scaled to 0.5mV.

to-noise performance of the whole system on one or more channels. For this reason, it is best to power the masthead from a constant-voltage transformer; in most cases, the constant-voltage transformer which supplies the station plant can be used also to control the masthead voltage.

PICTURE DEFINITION

Unfortunately, there occurs a progressive deterioration in picture quality from the start to the termination of a large network. Again, this is caused by a large number of repeaters being connected in tandem. The full vision bandwidth should be maintained at the aerial station, and converters and amplifiers in this critical position should have their alignment checked preferably by the oscilloscope/wobbulator technique.

On a modern receiver, the 3mc/s bars of Test Card "C" should have fairly reasonable definition and freedom from overshoot. When this high quality has been fully achieved at the aerial station, the signal will be found to hold its quality over an extensive section of network. However, if the definition is sadly lacking at the aerial station, then the quality usually appears to deteriorate much more rapidly on the networ.k

If a very low signal is being distributed, it will almost certainly be impossible to eliminate picture noise, and in this case it sometimes pays to decrease the bandwidth of the associated amplifier or converter. The definition is impaired, of course, but the noise effect is also reduced, and it has been proved that most viewers are able to tolerate poor definition more than picture noise. A reduction to 2 mc/s has surprisingly small effect on an actual picture, but aids considerably in removing grain.

CROSS MODULATION

This is one of the biggest problems to all relay operators, and is the reason why this heading has appeared several times in past chapters.

Cross-modulation is the result of non-linearity somewhere in the system. The various distribution signals at such non-linearity point tend to modulate each other. The result is "cross-talk' between channels, causing either a ghost picture from one channel to appear on the picture of the channel being viewed, or sound-on-vision and vision-on-sound.

Cross-modulation rarely occurs in the network system, but is invariably the result of non-linearity in one or more of the repeater amplifiers. An amplifier is linear (or nearly so) up to a certain output voltage, according to the design, but above that output it becomes non-linear. One cause of cross-modulation is a poorly designed system is that in order to supply end-of-spur subscribers with adequate signal the repeater output may require to be advanced beyond the cross-modulation margin.

MAY START TROUBLE

Moreover, if a repeater is adjusted to a gain setting just below the apparent cross-modulation point, a slight drop in power voltage may be sufficient to incite cross-modulation. This trouble is aggravated if the repeater features an automatic control of gain, for then a fall in gain due to a fall in power voltage (especially heater voltage) will be compensated by the AGC action, and this will push the repeater even further into cross modulation.

Most repeaters have some means of measuring the output voltage, either at a test point or tee junction. Care should always be taken to ensure that the output is at least 20 per cent. below the voltage at which cross-modulation becomes troublesome. This then gives a reasonable tolerance for power voltage variations and alteration in attenuation of the network cable due to temperature change. The latter factor, of course, is usually taken care of at the various AGC points throughout the system.

The diagram in Fig. 38 shows the working limits of a typical Band 1 repeater. It will be seen that the signal voltage in the cable falls along the length of the cable until it is in the region of +12dB. At that point the repeater pushes up the output again to around +42dB. If the output is increased to about +50dB, the repeater is close to the point of cross-modulation. Further, if the signal applied to a repeater is less than about +10dB, there is the danger of the repeater itself contributing to network noise.

In addition, there is always the possibility of the signal radiated from the cable close to the output of a repeater being troublesome in poor off-air signal areas if the output is increased to a large value. This may, of course, be possible if the repeater is carrying only one or two television programmes, for cross-modulation performance relates to the total output signal of all channels, and not just a single carrier.

CHAPTER TWELVE

Communal Aerial Systems

EMPHASIS has so far been on the relatively large coaxial relay system, which would be adopted in a town or large village. There remains, however, considerable potential for the smaller type of relay—sometimes called a shared aerial system or communal aerial system—in blocks of flats, housing estates and small villages.

In past chapters much has been said concerning the desirability of converting Band 3 channels to suitable channels in Band 1, for such reasons as ease of distribution and economy related to smaller losses at lower frequencies. However, in a small system this may not apply to the same extent, for the cable lengths will be smaller and most of the distribution losses may not occur in the cable but in splitters and subscribers' take-offs.

In other words, the losses contributed by the network equipment may be well above the smaller losses of the cable at Band 1 frequencies. It must be remembered that the losses of splitters and take-offs are usually substantially the same at any frequency from Band 1 to Band 3.

MAIN CABLE ATTENUATIONS

Thus, on a small estate or block of flats, the main cable attenuation may only be about 5dB on Band 1, which would make it about 10dB on Band 3. The remainder of the losses (possibly 20 or 30dB) would be contributed by the network items. Looking at the problem from that angle hardly warrants the expense of conversion.

There is another angle, however: at some later date it may be desirable to connect the small system to a larger town system. This could prove costly and difficult if the smaller system is designed for Band 1 and Band 3 distribution. Moreover, small systems, operating on their own master aerials, are sometimes undertaken in a town which is being wired in total on the large system basis. When this is the case, each small system should be designed in conformity with the large system so that they can all easily be coupled together when the main trunk cable is sufficiently expanded.

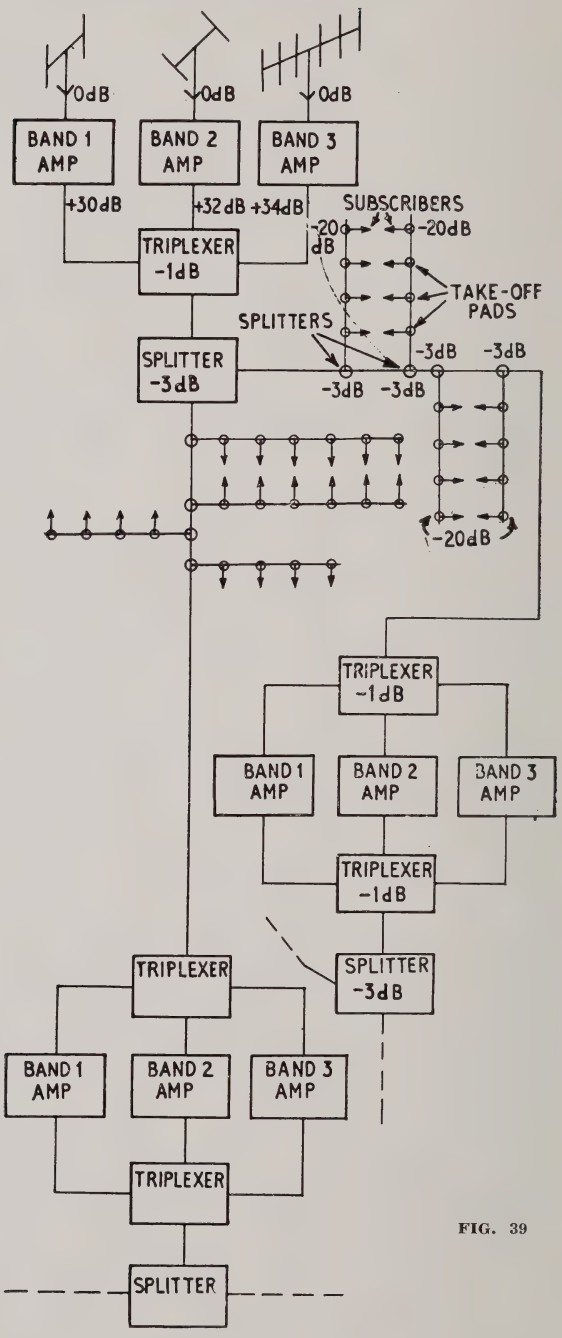


Fig. 39.—Wiring diagram of a small relay system, such as may be used on a small housing estate. 0dB equals 500 microvolts, and cable losses per 100 yds. are as follows: Band 1, 5dB; Band 2, 7dB; Band 3, 10dB.

FIG. 39

Generally speaking, provided the distribution area is compact, up to 500 subscribers can be fed from a Band 1/Band 3 system without much difficulty. For larger systems, conversions to Band 1 channels may be desirable. This does not apply, of course, to the EMI system, which is designed in entirety to distribute over a very wide frequency spectrum, embracing Bands 1, 2 and 3, even in large towns.

SIGNAL LEVELS

In most cases, it will be decided not to convert. The project may be a housing estate of, say, 100 dwellings, and the call may be for BBC and ITA television and the VHF/FM signals. Irrespective of the signals in the master aerials, each subscriber should have a minimum of 500 microvolts on each vision carrier and a minimum of 250 microvolts on each sound carrier, including VHF/FM. Some authorities put this minimum level at 1mV vision and 500 microvolts sound, but in the author's opinion this is unnecessarily high, bearing in mind that ordinary domestic receivers will be used, which operate admirably with excellent signal-to-noise performance at 500 microvolts vision and 250 microvolts sound.

Indeed, with the improved sensitivity of receivers attributable to frame grid valves, a vision signal level above 1mV may demand the use of subscribers' attenuators to avoid overloading troubles at the receivers!

Even if special receivers are designed for coaxial relay, which is quite likely, there would be no difficulty in producing a set at a very reasonable cost with a vision sensitivity suitable for a 500 microvolt input signal, with adequate tolerance to cater for sensitivity fall-off with age, etc.

Using a total of four frame-grid valves, including the two in the tuner, Mullard have designed a circuit with a sensitivity of 71 microvolts on Band 1 for 2V DC at the detector! Thus, an inexpensive coaxial relay receiver is possible.

Having decided on the channels and the signal levels, the next move is to find a suitable site for the master aerials. The type of aerials selected will depend upon the prevailing signal conditions and local interference, which is likely to be higher on an estate than on a site isolated from domestic electrical equipment. The estate controller or owner will usually made a site available for the relay aerials, but, unfortunately, his idea of a site may not suit the technicalities of the case!

It is usually stipulated that the aerials have to be as unobtrusive as possible. It may be possible to erect a small tower in the corner of the estate or one of the houses or a block of flats may have to accommodate the aerials in the ordinary way.

CHOOSING THE SITE

The site should not be chosen without considerable thought. An extensive test of the signal conditions and interference level at the proposed site should be made over a period of at least a week. These tests

will also dictate the type of aerial most suited to the conditions, for even if the signal pick-up is high, high-gain aerials may, nevertheless, be required to reduce interference or to get rid of a ghost.

In Fig. 39 is shown a part of a plan that may well be used in the project under consideration. Zero dB is taken as 500 microvolts, and it is assumed that signals of this level are present at the downlead of each aerial. Separate amplifiers are employed for each Band or channel and, after amplification, the signals are combined either in a mixer or triplexer, as shown. The combined signals are then fed to a splitter which serves two outgoing cables. Additional splitters are introduced as required along the outgoing cables to feed spur cables, and the spur cables feed subscribers' downleads through take-off pads.

Since it is required for each subscriber to have a signal level of 500 microvolts, or 0dB, the total loss from the output of the amplifiers to the most distant subscriber must not exceed the gain of the amplifiers. In the diagram, the gain of the Band 1 amplifier, for example, is set at 30dB. Thus, the loss on Band 1, including the triplexer, splitters, cable and subscriber's pad must not exceed—30dB; this applies to any subscriber.

It will be noted that the Band 2 and 3 amplifiers are adjusted for a slightly higher gain. This is because the cable losses are progressively higher on those Bands in comparison to the loss on Band 1. The loss in the network items should not differ greatly over Bands 1, 2 and 3.

POST OFFICE STIPULATION

The attenuation of the most distant subscriber's take-off pad must never be less than—18dB. This is a stipulation made by the Post Office to ensure that adequate isolation exists between adjacent subscribers. A smaller isolation may result in interference between receivers connected to the system. Moreover, each subscriber's outlet must be isolated from the cable system either by a transformer or by a capacitor (not exceeding 0.005mF) in series with each conductor of the downlead. The capacitor method is favoured in small systems, and isolated outlet boxes incorporating the requisite isolation capacitors are readily obtainable.

Where the size of the project demands more than a single bank of amplifiers, additional banks are introduced at the terminations of the main outgoing cables. The diagram also shows how the signals are separated and applied to the appropriate amplifiers. Triplexers are suitable for this operation, and also for combining the signals again after amplification; triplexers have less insertion loss than resistive splitters and combiners.

The total attenuation of the main cable network, between one amplifier system and another, should not exceed the gain of the first amplifier in decibels. However, it will usually be found that the inter-repeater loss is less than the amplifier gain. In that case, the gain of the second amplifier system should be adjusted to a smaller value than the first one.

For example, if the inter-repeater loss is only 20dB, and the first amplifier system has a nominal gain of 30dB, as in the diagram, a signal level of +10dB will be present at the input of the second amplifier system. Thus, the second amplifier system should be adjusted for a nominal gain of 20dB, so as to provide a nominal signal level of + 30dB at its output, the same as at the output of the first amplifier system.

When working in decibels the gains and losses can easily be added and subtracted, and the overall plan can be worked out without difficulty. However, one must always bear in mind that an amplifier can only provide a certain output signal level. If the specified output is exceeded cross-modulation will occur between the sound and vision signals, and if an ever greater output is attempted the output valve will saturate and the signals will be badly distorted.

Repeaters and amplifiers for small systems are usually capable of providing 150mV on each carrier with good cross modulation performance. If 0dB is taken as 500 microvolts, then 150mV is up on 500 microvolts by 300 times, which is almost 50dB. However, it is advisable to operate within a reasonable tolerance, especially on a system without AGC, and the maximum output per carrier would be limited to 100mV, or 46dB.

Thus, during the planning of a system, the output from any amplifier should never be greater than 46dB. As an example, if the aerial signal is 0dB, but if the aerial signal is, say +14dB, then the amplifier gain could only be taken up to 32dB, because the signal output is equal to the gain of the amplifier plus the applied signal—both in decibels. This also applies to intermediate amplifiers.

If, on the other hand, the aerial signal (on any channel) is substantially below 0dB, a low-noise aerial amplifier should be interposed between the aerial and the main amplifier to bring the signal applied to the main amplifier up to 0dB or a little above. With an aerial signal of, say,—10dB and a signal level requirement of 30dB, a total of 40dB gain is needed. The aerial amplifier could contribute 15dB and the main amplifier 25dB.

It should be noted that the splitters in the diagram of Fig. 39 have an insertion loss of 3dB to the main cable and 3dB to the spur cable. Other resistive splitters would have a greater spur loss than this, though possibly a smaller insertion loss to the main cable.

DUAL CHANNEL AMPLIFIERS

In Fig. 39 separate amplifiers are shown for Bands 1 and 3. There are available, however, dual channel amplifiers which will amplify, simultaneously, one channel in Band 1 and one in Band 3 in any combination. As the same valves are used for the two channels a considerable saving is evident. Each section provides a gain in the region of 36dB, fixed on Band 3 and variable on Band 1 to allow equalisation of the signals fed to the system.

Such amplifiers are also useful for feeding a number of TV and FM

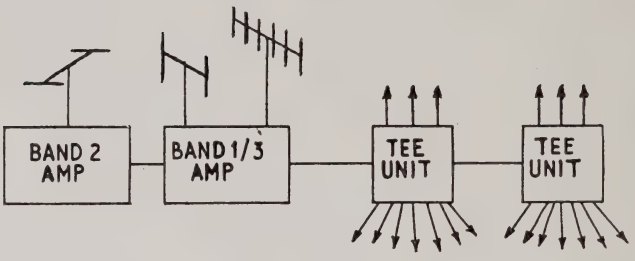


FIG. 40

Fig. 40.—A small extended aerial system suitable for television showrooms and the service department, or for a block of flats. The tee units may have from five to nine outlets each.

outlets in showrooms and the service workshop. FM is added by the use of a separate FM amplifier which is connected to the TV amplifier through coaxial links.

A simple arrangement for feeding a total of 18 outlets is shown in Fig. 40. Two tee units are adopted, each having nine outlets to feed separate receivers. The tee units are available with from five to nine outlets with a tee loss from 20 to 38dB, depending upon requirements. The insertion loss to the main cable ranges from 0.3dB to 4.2dB, governed by the tee loss and the number of outlets.

Such a system could, of course, be extended to feed a block of flats, or a tee unit could be incorporated in an estate system to provide the same facility, for it is often found that blocks of flats are co-sited with semi-detached houses.

It is becoming the practice of local authorities to stipulate a standby amplifier in communal aerial installations for blocks of flats.

Electrical contractors and radio dealers are showing more interest in tendering for aerial installations which, at one time, seemed the prerogative of the large relay contractor. An engineer fairly new to extended aerial systems may visualise coaxial changeover switches and other similar complications for changing from a main to a standby amplifier in the event of failure.

On the face of it, such devices would be required and contractors may, in fact, tender with these in mind.

SIMPLE MAIN/STANDBY CHANGEOVER

However, there is a simple method of changing from the main to the standby amplifier system—or vice versa—without any coaxial network complications whatever. The method is based on the "star network" and the system as a whole is planned with both amplifiers in circuit signalwise.

Changeover is accomplished by switching off the power to the faulty amplifier system and switching on the power to the standby amplifier.

A simple mains changeover switch is all that is required and may

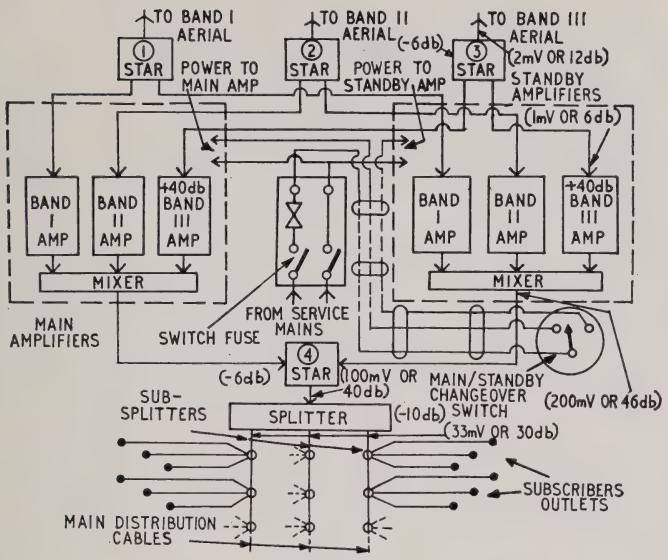
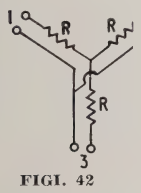


FIG. 41

Fig. 41.—Block diagram of a complete changeover installation, in which the main standby switch can be situated remotely without affecting the RF network.



FIGI. 42

Fig. 42.—(Above) Shows a three-point star network.

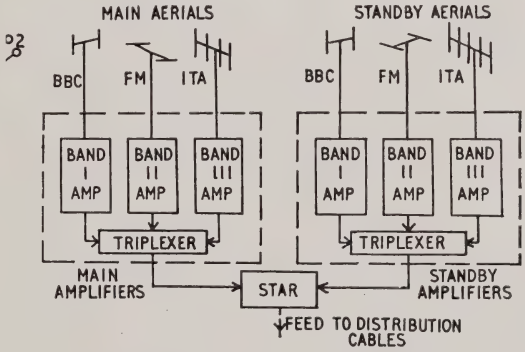


FIG. 43

Fig. 43.—(Right) Illustrates a system where each amplifier has its own aerial.

be sited near the amplifiers or at a more convenient point, such as in the office of the janitor or caretaker. The latter position is, of course, to be preferred since, in the majority of cases, the amplifiers are hidden in the roof-space or at some other inaccessible place near the feeds from the master aerial.

BLOCK DIAGRAM

Fig. 41 shows a block diagram of a complete installation. As extended aerial systems invariably employ direct carrier frequencies (e.g., conversion from Band 3 channels to Band 1 channels is not adopted), a separate amplifier is required for each of the three bands.

The system of main amplifiers is within the broken line at the top left-hand corner of the diagram, while the system of standby amplifiers is within the broken line at the top right.

Signals from the master aerials are fed to the inputs "stars" 1, 2 and 3 which feed both the main and standby amplifiers. The outputs from each amplifier system are combined in their respective mixers, and the combined main and standby outputs are fed to "star" number 4.

This feeds the signals into the main splitter and thence to the distribution cables, as shown. On the distribution cables are located the usual subsidiary splitters or similar arrangements to feed subscribers' outlets.

Power for the amplifier systems is picked up from the service mains in the ordinary way (usually from the landlord's lighting system). This is passed through the necessary switch-fuse and thence either to the main or standby amplifiers as controlled by the "main/standby" change-over switch.

In Fig. 42 is shown the circuit of a three-terminal star network of the type required in the installation. This is available commercially from most manufacturers dealing in relay and extended aerial equipment and also from certain aerial manufacturers. It is also easily made up, as required, in a conduit box or similar container.

Value of resistors R depends on the number of terminations required and on the resistance or impedance which will be connected to the terminations. R can be computed from the expression : $R = Zo\ (n - 1/n + 1)$, where Zo is the characteristic impedance of the cable and n is the number of points either feeding in or being fed. With two terminations, as in Fig. 42, and for a characteristic impedance of 72 ohms, the resistors must each be approximately 24 ohms.

The star network provides an overall impedance match as required at each of its terminations, but it does so only at the cost of some signal strength. For example, with the network shown in Fig. 42, the voltage loss is 6dB or 2-to-1. This means that the aerial signal at each of the amplifiers will be half the strength of the signal actually at the end of the aerial downlead. This is usually of no consequence as the signal strength induced into a master aerial of a flat system is generally well above the working strength required for noise-free distribution.

Similarly, there is a loss of 6dB at the output of star number 4 in relation to the signals appearing at the output of the mixer, but again, this can be taken into account during the normal planning of the system as a whole.

When planning system is carrying three bands the highest frequency is used for determining cable losses and amplifier gains. If we adopt this principle in relation to Fig. 41 and assume that the Band 3 aerial signal

is 2mV, then the signal actually applied to each of the Band 3 amplifiers is 1mV.

It is best to work in decibels, so if we make 0dB, say, 0.5mV the aerial signal is +12dB and the amplier signal +6dB (e.g., +12 minus the 6 lost in the star). If the amplifier gain is set to 40dB, the output at the mixer (assuming this has zero loss), is 46dB (200mV).

The loss in star number 4 will reduce this to 40dB (100mV), which will be the signal level fed to the main splitter.

If the splitter is a four terminal type of the star variety as shown, then at *each* of the three outputs the signal will be 30dB (33mV approximately) because a four terminal star introduces a loss to each output of approximately –10dB. Assuming that the cable and subsidiary splitter loading losses equal 10dB on the Band 3 channel used and the final splitter has a "T" loss of 20dB (making a total loss of –30dB), the signal at the most distant subscriber's outlet will be 0dB which, as was set in the first place, is 0.5mV.

At subscribers' outlets fed from intermediate subsidiary splitter, the signal level will be above 0dB, depending on the losses up to that point. In normal practice, of course, the splitters would be arranged to have a "T" loss to balance the signal at the point of connection in the distribution cable and to provide the subscribers fed from it with a signal of accepted level (0.5 to 1mV).

Cable losses would be slightly less on Bands 1 and 2 and the signal level or gain controls on those amplifiers would be adjusted to suit the Band 3 planning.

From this it is clear that the network can be designed signalwise to cater for the extra fixed loading of a standby amplifier system, and all that is necessary to change from one to the other is a switched power supply.

It is unusual for an authority to stipulate standby aerials as well as standby amplifiers, but should ever such a case arise, the installation could be simplified to that shown in Fig. 43. Here, stars 1, 2 and 3 are eliminated and each amplifier is fed from its own aerial.

CHAPTER THIRTEEN

Review of Equipment

IN this concluding chapter it is my aim to review the relay situation and to give a few details of currently available relay equipment. As relay is expanding at a fantastic rate, and more and more manufacturers are entering the field, it is impossible to give more than just a bird's-eye view of the situation as it stands today.

There are over 449,000 TV relay subscribers, of which 78,000 are on coaxial systems (these figures relate to the end of 1960), and the number is increasing rapidly.

Considerable sums of money had already been expended in the original scramble to put in relay, and there has been real "fun and games" in the fight for council concessions. Recently there has been the introduction of new systems, engineered in different ways, with further capital investment. However, the situation would now appear to be coming under some sort of control. Organisations are entering relay in a much more selective way. Relay is here—not just—to stay but to expand. Since it is a *service* to the public, there is every possibility that it will extend beyond the scope of the broadcast signal in the future.

If pay-television comes to pass, which is not all that unlikely, wired systems will really come into their own.

A good *coaxial* system, properly engineered in terms of *system* as distinct from individual items of equipment, will cope with future requirements. Coaxial relay is very simple to instal, regarded just as a communal aerial, but it is a very different matter when a system is built upon a solid engineering foundation which must take into account engineering tolerances and good engineering practice. A badly installed system could *never* be suitable for higher definition signals and colour, and it would not make the grade should pay-television arrive.

One can never tell what the future holds, but it is economic folly to spend thousands of pounds installing a system that is incapable of being expanded in programme capacity. This is a most important point that must be considered along with immediate requirements.

Basically there are two ideas on this: one is to instal a system

today which will take care of tomorrow's needs; the other is to instal a system that meets today's requirements but which can be expanded easily tomorrow.

Both courses present difficult decisions since no authority has yet outlined a basic plan on which relay should go forward. Hence, the immediate need for a properly engineered *system,* including channel allocation, from the coaxial system point of view.

HIGH STANDARD

Equipment manufacturers have played their part admirably in helping to bring coaxial relay to the present high standard of development. It has not been easy to obtain: a multiplicity of modulated carriers with less than 1 per cent. cross-view at high level in wideband amplifiers; to minimise standing-waves on networks; to convert frequencies without loss in quality; and to secure the hundred-and-one other things that coaxial relay calls for.

Completion of these tasks opens the way to phase two of exercise "coaxial relay."

Individual items of relay equipment have been very well engineered. Repeaters are now able to provide eight modulated carriers, each at a level of 140mV with cross-view better than 50 dB (Teleng); or 24 modulated carriers at 100mV (EMI). The EMI system, it will be recalled, uses so-called distributed amplifiers operating over a very wide frequency range, while the Teleng arrangement, in common with other Band 1 systems, uses a three-stage stagger-tuned amplifier. The former uses 12 valves and the latter three. Belling & Lee also use a distributed amplifier up to about 100 Mc/s.

The problem has been in obtaining high output on a large number of carriers with adequate cross-modulation margin. The harder a valve is pushed the more it goes into the non-linear region—and cross-modulation is a function of non-linearity. Valves are able to provide quite high RF outputs, even a VHF on a single carrier before saturating or clipping, but when more than one carrier is introduced, trouble starts. Output is considerably curtailed, since to go anywhere near the saturation mark causes severe non-linearity—and cross-modulation.

Larger valves are now used in the output stages of repeaters to alleviate this problem, but yet larger valves seem to be required for future equipment—and large valves bring powering problems.

THREE BASIC FORMS

Converters take three basic forms. First, the simple "frequency changer" type converter; this has several problems, one of which is its inability to convert to certain channel combinations without pattern interference. Nevertheless, this simple sype of unit has much to commend it under certain operating conditions, and a very well made version is often better in practice than more complicated devices.

Second, the so-called "double converter" type: this employs the first

"frequency changer" to convert to IF and the second to convert from IF up to the required channel in Band 1. With this arrangement any Band 3 channel can be converted to any Band 1 channel without interference. AGC is also sometimes applied to the IF stages.

Third, the "retransmission" arrangement: a frequency changer (sometimes standard turret tuner) converts the required Band 3 channel to sound and vision intermediate frequencies. The signals are demodulated, as in an ordinary TV set, and amplified. The resulting audio and video are then modulated on crystal-controlled carriers at frequencies corresponding to the required Band 1 distribution channel. This type also has sound and vision AGC at IF, sync reinsertion and other somewhat complicated circuits to modulate the video without distortion and phase shift. Such a unit can provide excellent results if correctly designed and adjusted, but otherwise can cause a lot of trouble.

The simple arrangement is favoured by the majority of manufacturers for certain applications, and an excellent unit of this nature is used by EMI. The double conversion system is favoured by Teleng, who introduced the idea some years ago. J. S. Fielden launched the "retransmission" idea for Viewline, and the system is in use in a number of Viewline systems up and down the country.

AGC systems are varied. EMI favours the pilot carrier arrangement. The carrier is rectified as selected repeater stations and the resulting DC voltage used as bias to control the gain. The bias varies, of course, in direct sympathy with alteration in cable attenuation, which may be caused by loading disturbances and temperature change.

Teleng and Fielden use AGC strips, built into the form of AGC units, after four or five repeater stations. Sound and vision on each channel are separated and applied to separate AGC strips with independent level adjustment. The Teleng system operates on the mean level of the vision carrier, which is quite edequate, while the Fielden system uses a pulse amplified black-level set-up, with attendant pulse generators and power units, etc.

WHEN FADING OCCURS

A few manufacturers have made provision for AGC of the pre-amplifiers. This is worth while in areas where fading is troublesome, if it can be applied correctly. Control amplifiers, ued after conversion or pre-amplification, sometimes provide AGC bias for the pre-amplifiers (EMI, for example).

There is plenty of equipment available for adding VHF/FM programmes to a TV coaxial system. AF/FM converter units permit other programmmes to be frequency-modulated in Band 2, in addition to the BBC FM programmes. Modulation can be from any source, such as from the audio derived from Continental stations. These added VHF "Programmes" are exclusive to relay subscribers.

Other methods of distributing sound include low-frequency carrier. Here a number of closely-spaced carriers are modulated by the required

programme material, the carriers then injected into the network. Subscribers receive the programmes on a multi-position switch unit and speaker. This arrangement is likely to help solve the problem of channel space on TV systems in the future.

Network equipment includes resistive splitters and subscriber taps, directional couplers (EMI), coaxial couplers (Teleng), and other various items, all of which have been dealt with in past chapters.

EQUIPMENT TOMORROW

Whereas to-day each carrier is launched at a relatively low signal level (approximately 100mV), it is likely that tomorrow's equipment will allow considerably higher launching levels (possibly in the region of 2V). This will make repeater stations more expensive than they are today; but, if wasteful resistive network losses are eliminated, and more use made of wideband transformers of ferrite and closed-core construction, then a single repeater station of the type envisaged will serve a very large distribution area without the need for booster repeaters.

Each carrier will need to be individually dealt with, and it is likely that wideband repeaters will lose favour in large systems, owing to the output of multiple signals being limited by cross-modulation in common amplifiers. This method, however, will make a large system more versatile than it is today, for then "carrier" amplifiers can be added only as and when required.

High signal levels will call for extra care in network matching, to avoid standing waves, and only really good cables will be suitable to avoid signal leakage and radiation. Cables of the "solid" outer conductor variety may well be necessary. Relay installation of the future may well be akin to plumbing!

In conclusion, I would like to record my thanks to manufacturers for their co-operation in placing such information at my disposal. I shall be glad to receive notice of any errors, and information of new equipment which I shall be able to deal with in revised editions of this book.

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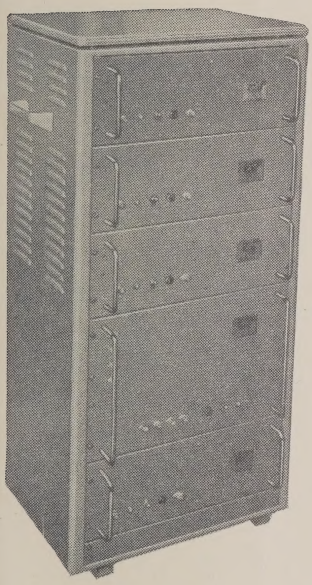
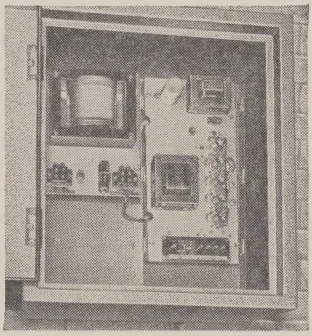


Belling-Lee main station source equipment

AS far back as 1937 " Belling-Lee " entered the broadcast relay field, with what was probably the first " piped " radio installation in a large block of flats in this country. To-day, although radio is more commonly included as an ancillary service in " piped " television systems, reliability, flexibility, and economy are still the chief features of all " Belling-Lee relay equipment.



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